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ABSTRACT

A project was designed to produce a broad description of current mining training programs and to evaluate their effectiveness with respect to reducing mine injuries. Aggregate training and injury data were used to evaluate the overall training effort at 300 mines as well as specific efforts in 12 categories of training course objectives. From such evaluations, recommendations were derived with particular emphasis being placed on identifying program characteristics that tend to be associated with effective training. Recommendations were also formulated with reference to role changes in industry and government interaction with respect to training programs, new or additional training programs, changes in the types of course materials and training methodologies, and recommendations concerning new areas for investigation. This second volume of a two-volume report is a detailed discussion of the quantitative data analysis and the resulting recommendations regarding a number of specific issues in the field of miner training. (Author/HD)

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Review and Evaluation of Current Training Programs Found in Various Mining Environments;

Volume II, Analysis and Recommendations

Prepared for

United States Department of the Interior
Bureau of Mines

by

U S DEPARTMENT OF HEALTH
EDUCATION & WELFARE
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16. Abstract

This document presents a description of the results of a project aimed at producing a broad description of current mining training programs and an evaluation of their effectiveness with respect to reducing mine injuries. Aggregate training and injury data were used to evaluate the overall training effort at 300 mines as well as specific efforts in twelve categories of training course objectives. From such evaluations, recommendations were derived with particular emphasis being placed on identifying program characteristics that tend to be associated with effective training. Recommendations were also formulated with reference to role changes in industry and government interaction with respect to training programs, new or additional training programs, changes in the types of course materials and training methodologies, and recommendations concerning new areas for investigation.

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DISCLAIMER NOTICE

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or of the U.S. Government.

FOREWORD

This report was prepared by the Bendix Corporation, Bendix Energy, Environment, and Technology Office, Ann Arbor, Michigan under USBM Contract Number S0144010. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of the Pittsburgh Mining and Safety Research Center with Mr. William Wichagen acting as the Technical Project Officer. Mr. John Blum was the Contract Administrator for the Bureau of Mines.

This report in two volumes is the final documentation of the work recently completed on the contract during the period July 1974 to November 1975. Volume I is a summary consisting of narrative description of several training programs found in a survey of the mining industry, the major results of an analysis of relationships between various measures of training and injuries, and the main conclusions and recommendations. Volume II is a more detailed discussion of the quantative data analysis and the resulting recommendations regarding a number of specific issues in the field of miner training. The draft summary volume was first submitted by the authors in July 1975, revised in September 1975, and after review by its MESA sponsors and industry representatives was resubmitted in December 1975 along with all the supporting data. This final version is limited to the summary and the complete narrative of the analysis and its implications.

We are grateful to the many individuals in government, industry, and labor for their time, interest, and inspiration for results of this review and evaluation of a very broad and complex topic.

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PHASE II ANALYSIS

SUMMARY

Introduction and Purpose

Training is recognized by government, industry, and labor as a key to the reduction of accidents due to human error and to the improvement of worker effeiciency. That this recognition takes the form of actions as well as words can be seen in current legislation, safety standards, investments in training, and local working agreements to facilitate training. Just as there are wide variations in both the characteristics and safety records of mines, there are also variations in the training programs. The objective of this study is to increase the understanding of how training course content, instructional methods, facilities, etc., can be associated with improved attitudes, modified behavior, and reduced mine accidents.

The purpose of this report of Phase II data analysis is to describe the relationships which appear to exist between training effort in various categories of safety program objectives and injuries attributed to corresponding categories of accident typologies. The variations found in the apparent linkage between training and injury rates as well as variations in emphasis in the sample population of mines are translated into a set of preliminary conclusions and recommendations.

Finding and Conclusions

Annual Data Set Cross-Sectional Analyses

The initial evaluation of the MESA injury and safety training data of some 180 coal mining operations based on cross-sectional analyses has resulted in the following findings:

- The relationships between injury rates and training rates for this large set of mines range between none and weak because variance in the injury rate for mines with the same training rate tends to be large. It appears that there is a group of mines in which safety training may contribute to the reduced injury rate and another group in which the injury rate appears to be independent of training rate.

---

1 Even if strong association is established, any indication of cause and effect would still have to be determined from analysis of time series data.

- The following injury types appear to be weakly associated with the corresponding training category:
  - A small group of mines for roof and face fall injury rate with respect to ground control training rate.
  - Haulage injury rate with respect to haulage training rate.
  - Electrical injury rate with respect to electrical training rate.
  - There is not enough material handling or machinery training to develop a relationship for the full set of mines analyzed.
  - There are not enough mines having ignitions/explosions injuries to develop a relationship.
- The relationships between overall injury rate (aggregate of all types) and the more generalized safety training rates not directed at specific injury types are as follows:
  - There is a weak linkage apparent between first aid training rate and overall injury rate.
  - Training in mine rescue, mine safety laws, general accident prevention, and safety program management appear to be independent of injury rate.
- The overall training rate appears to be independent of injury severity (total lost days).
- An important series of findings are obtained from a comparison of the distributions of total injuries by cause (1972-1974) and total training in employee courses in each corresponding category listed in Table 1.

TABLE 1

DISTRIBUTIONS OF INJURIES AND TRAINING EMPHASIS

	% of Injuries	%of Employee-Courses
Roof fall and ground control	14.47	11.27
Handling materials and material handling & storage	13.80	0.01
Haulage and haulage safety	12.50	0.55
Machinery and machinery qual/safety	19.67	0.07
Slip/fall & lift/pull and general accident prevention	27.53	3.67
Electrical and electrical qual/requal.	0.51	4.45
Explosion/Ignitions and explosive safety/mine atmosphere testing	2.43	41.8

The emphasis of training is out of balance with relative level of the corresponding types of injuries. Either the emphasis on training exceeds the relative position of the injury cause (electrical and explosive/ignitions) or not enough training is being given for the number of injuries (machinery, slip/fall, haulage, material handling). The only injury type and training objective category that approach a balance are roof fall and gournd control training.

Another view of this data might be that where training by cause is extensive the injury rate by cause is low. Where the training is limited the injury rate high.

- The sample size of about 180 mines is representative of the total sample of training. A comparison of the percentage distribution of courses taught for the sample coal mines over three years compared to all coal mines for the first six months of 1974[2] exhibits little change except in general accident pre-

2 The sample coal mines gave 206,000 employee courses in 2.5 years. All coal operations conducted 354,000 employee-courses in the first six month of 1974.

vention and first aid training. These two deviate almost 4%. All the other differences are equal to or less than 1%. The differences can be attributed to either the difference in the two training data sets or a slight change in emphasis in 1974 from the other two years.

The main conclusions drawn from cross-sectional analysis are:

- Because the relationship between total training rate and total injury rate for the entire set of sample mines is weak at best, any evidence of both stronger associations and cause and effect is going to come from different approaches.[3] It is apparent, however, that training is not the only factor associated with injuryrate because some mines decrease in injuryrate without an increase in training rate. A sizeable number of mines have had and still have both a low injury and a low training rate. No decrease is possible for these mines.

- If there is a limitation in the amount of training, then an adjustment in emphasis of training should be made. More courses should be given in machinery, haulage, material handling and general accident prevention. Less training should be given in electrical and explosions/ignitions. If the training is increased, then the increase should be in machinery, haulage, material handling, general accident prevention, and roof control courses.

Quarterly Data Set Time Series Analyses

Several general patterns were found in the quarterly time series data including:

- Injuries tend to preceed training in the data set. The occurrence is statistically significant which means that there is a valid reason. Injuries have been occurring over many years while the MESA training programs are starting up throughout the period. Another possible contributing cause is the hypothesis that injuries lead to training.

- An important finding is that training leads to reduced injury rate. The finding is statistically significant and the relationship causal. It is determined for a comparable injury data set without training that the injury rate behaves randomly in a statistically significant manner.

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3 The fact that categories of objectives where the most training has been given have the lower injury rates (electrical and explosions/ignitions) and where lesser levels of training had been given the injury rates are higher (lift/pull, machinery, handling materials' haulage) indicates that training might be correleated to injury rate.

- General Accident Prevention Training is related to all types of injuries in a statistically significant and causal manner.

- A quarter in which training is given will be followed by a reduced injury rate in two successive quarters in at least 25 to 40 percent (depending upon the type of injury and caterory of training) of the instances with 99 percent confidence. Similarly it can be expected that the training will lead to two successive increases in injury rate in only 5 to 15 percent of the quarters given with 99 percent confidence.

- Finally, the quarterly MESA data for injuries and training comprises a useful data set from which statistically significant and instructive findings can be drawn.

Analysis of specific injury types versus the category of training whose general objective is to prevent or reduce that type of injury found that:

- Haulage Training Rate versus Haulage Injury Rate:

  - Of 176 mines examined both injuries and training was reported by 53 mines.

  - Of the 101 quarters in which training was given, 39 quarters were evaluated as effective, 6 quarters were found to be ineffective, and 56 quarters could not be evaluated.[4] The training was effective 39 percent of the time and ineffective 6 percent of the time.

  - It is determined that semi annual training would be more than twice as effective as annual training (twice a year at a given site rather than to an individual).

- Ground Control Training Rate versus Roof and Face Fall Injury Rate:

  - Of 181 mines examined, both injuries and training were reported by 131 mines.

---

4 Cases where the training continued in the next quarter and (because the evaluation criteria was based on the next two quarterly injury rates) the last two quarters of the time series could not be evaluated.

- Of the 459 quarters in which training was given, the training was effective 138 times, ineffective only 31 times, and unclear 290 times. The training was effective 30 percent of the time, ineffective 3 percent and unclear 67 percent of the training quarters.

- General Accident Prevention-Training Rate versus Handling Materials Injury Rate:

  - Of 181 mines examined, both injuries and training were reported by 102 mines.

  - Of the 265 quarters in which training was given, training was effective 75 times, ineffective 21 times, and unclear 169 times. The training was effective 28 percent of the time, ineffective 8 percent, and unclear in 64 percent of the training quarters.

- Machinery Training Rate versus Machinery Injury Rate:

  - Of 181 mines examined, both injuries and training were reported by 22 mines.

  - Of the 29 quarters in which training was given, training was effective 8 times, ineffective twice and unclear 19 times. The training was effective 28 percent of the time, ineffective 7 percent, and unclear 65 percent in quarters that could not be evaluated.

- Electrical Training Rate versus Electrical Injury Rate:

  - Of the 179 mines examined, both injuries and training were reported by 77 mines.

  - Of the 237 quarters in which training was given, it was evaluated as effective 60 times, ineffective 9 times, and unclear in 168 cases. The training was effective 25 percent of the time, ineffective 4 percent and unclear in 71 percent of the quarters.

- General Accident Prevention Training Rate versus Lift/Pull and Slip/Fall Injury Rate:

- Of the 181 mines examined, both injuries and training were reported by 115 mines.

- Of the 308 quarters in which training was given, training was found to be effective 94 times, ineffective 43 times and could not be evaluated 169 times. The training was effective 31 percent of the time, ineffective 14 percent, and unclear in 55 percent of the cases analyzed.

- Explosives Safety and Explosive Atmosphere Detection Training Rate versus Explosion/Ignition Injury Rate:

  - Of the 180 mines examined both injuries and training were reported by only 24 mines.

  - Of the 103 quarters in which training was given, it was evaluated as effective 26 times, ineffective only 3 times, and 74 training quarters could not be evaluated. The training was effective 25 percent of the time, ineffective 3 percent and unclear in 72 percent of the cases.

- General Accident Prevention-Training Rate versus Total Injury Rate:

  - Of the 180 mines examined both injuries and training were reported by 126 mines.

  - Of the 320 quarters in which training was given, general accident prevention training was effective for 109, ineffective for 50, and unclear for 161. The total injury rate was reduced in at least two subsequent quarters for 25 percent of the training quarters, ineffective for 16 percent, and unclear for 50 percent of the cases examined.

DATA MANAGEMENT

Input Data Description

There are two data sets that were obtained from MESA which are separate and distinct. The first set of data includes employment, production and accident data. A portion of the first set of data is given in Table 2. These basic and overall injury data are aggregated by quarter, year, and over the total period of 1972 to 1974.

TABLE 2

BASIC AND ACCIDENT DATA:[5]
VARIABLES 1-6

Variable No.	Name
V1	Employment
V2	Hours of exposure
V3	Tons of production
V4	Fatal injuries
V5	Non-fatal injuries
V6	Man-days of lost time

INJURIES BY CAUSE: VARIABLES 7-13

V7	Roof or face fall, bump or burst
V8	Handling materials
V9	Haulage
V10	Electricity
V11	Explosions/ignitions
V12	Lift/pull or slip/fall
V13	Machinery/hand tools

The second portion of the first set of data is separated into seven cause categories. Fatal and non-fatal injuries are combined in this data.

The second set of data in Table 3 relate to training. These data were reduced into thirteen employee-course categories from a larger set

5 There are also partially complete annual State data, from 1968-1973, of the type found in Table 2.

of courses. (An employee-course is one employee taking one course). Because of the variability from course to course in the course length, data course hours by category were not incorporated in this analysis plan. The data are entered on the data sheet by category number.

TABLE 3

EMPLOYEE COURSES BY CATEGORY: VARIABLES 14-26

Variable No.	Name
V14	Ground/roof and rib control -Category 1
V15	Material handling and storage-Category 2
V16	Haulage - Category 3
V17	Electrical - Category 4
V18	Explosives - Category 6
V19	Machinery - Category 7
V20	General accident prevention - Cagegory 8
V21	First aid - Category 9
V22	Self resuce/mine rescue - Category 10
V23	Methane/explosive atmosphere detection kit - Category 11
V24	Non-explosive gas deficiency detection - Category 12
V25	Safety (mining) laws - Category 13
V26	Safety/management training -Category 14

The data are coded by individual mines. An identification number was used that includes a three-digit Bendix mine ID number, and a letter giving the level of aggregation and data source. The data sets include mines with MESA data only, state data only, and both. The Bendix mine ID numbering system is illustrated in Table 4.

TABLE 4

BENDIX ID NUMBERS

Bendix No.	Company and Mine	BuMines No.
001	Mine Company "A"	
002	Illinois mine of Company "A"	11-00877
003	Indiana mine of Company "A"	12-01031
...		
006	Mine Company "B"	...
...		...

The fourth column in the field is the level of aggregation and the source of the data. The meaning of the letter entries are given in Table 5.

TABLE 5

AGGREGATION LEVEL AND SOURCE

A. State, 1968
B. State, 1969
C. State, 1970
D. State, 1971
E. MESA, 1st Qtr 1972
F. MESA, 2nd Qtr 1972
G. MESA, 3rd Qtr 1972
H. MESA, 4th Qtr 1972
J. MESA, 1972
K. State, 1972
L. MESA, 1st Qtr 1973
M. MESA, 2nd Qtr 1973
N. MESA, 3rd Qtr 1973
P. MESA, 4th Qtr 1973
Q. MESA, 1973
R. State, 1973
S. MESA, 1st Qtr 1974
T. MESA, 2nd Qtr 1974
U. MESA, 1974
V. MESA, (1972-1974)

Each case (mine) is identified by a three digit number and a letter. Case 002J is the case number for the Illinois mine of Company "A" with the file record containing data for an aggregation of the 1972 MESA quarterly data into 1972 annual data. The 20 possible aggregations of injuries and training over time are indicated by the letters A through V in Table 5.

Derived Variables

The raw data could be plotted (e.g., non-fatal injuries versus production) and put into histograms (total production of all the mines in a series of contiguous intervals versus frequency). However, there is a need for derived variables that: (1) have more meaning to the industry, (2) obtain rates to allow valid comparisons between mines and time intervals, (3) relate training and injuries to production, (4) obtain injury severity, etc. These derived variables were used in the analysis to identify relationships instead of the raw data.

The first set of derived variables are summations (total employee courses), rates (injuries per million man-hours), and ratios of rates (employee courses per thousand tons of production). None of these variables separate injuries and training by cause category. The variables are listed in Table 6.

The next two sets of derived variables separate injuries and courses by causes and categories, respectively. Table 7 lists the variables for injury rates by cause and Table 8 lists employee-course rates by category.

TABLE 6

SUMMATIONS AND AGGREGATE RATES

Variable No.	Name
V27	Injury rate in injuries per million man-hours of exposure (MMII) $\frac{(V4 + V5) \cdot 10^6}{V2}$
V28	Productivity in tons per man-day $\frac{8 \cdot V3}{V2}$

TABLE 6 (cont.)

Variable No.	Name
V29	Average lost days per non-fatal injury $\frac{V6}{V5}$
V30	Average lost days per injury[6] $\frac{(6000 \cdot V4) + V6}{V4 + V5}$
V31	Total lost days per thousand tons of production $\frac{V30 \cdot (V4 + V5) \cdot 10^3}{V3}$
V32	Total employee courses V14 + V15 + V16 + V17 + V18 + V19 + V20 + V21 + V22 + V23 + V24 + V25 + V26
V33	Total employee courses per employee $\frac{V32}{V1}$
V34	Employee courses per thousand tons of production $\frac{V32 \cdot 10^3}{V3}$
V35	Total Employee courses per MMH $\frac{V32 \cdot 10^6}{V2}$

6 The standard multiplier for the number of lost days that are attributed to a fatality is 6,000.

TABLE 6 (cont.)

Variable No.	Name
V36	Total lost days per MMH $\frac{V30 \cdot (V4 + V5) \cdot 10^6}{V2}$

TABLE 7

INJURY RATES BY CAUSE TYPOLOGIES

Variable No.	Name
V37	Roof fall injury rate in injuries per MMH $\frac{V7 \cdot 10^6}{V2}$
V38	Handling materials injury rate in injuries per MMH $\frac{V8 \cdot 10^6}{V2}$
V39	Haulage injury rate in injuries per MMH $\frac{V9 \cdot 10^6}{V2}$
V40	Electrical injury rate in injuries per MMH $\frac{V10 \cdot 10^6}{V2}$
V41	Explosions/ignitions injury rate in injuries per MMH $\frac{V11 \cdot 10^6}{V2}$

TABLE 7 (cont.)

Variable No.	Name
V42	Lift/pull and slip/fall injury rate in injuries per MMH $\frac{V12 \cdot 10^6}{V2}$
V43	Machinery/hand tool injury rate in injuries per MMH $\frac{V13 \cdot 10^6}{V2}$
V44	All other injury rates in injuries per MMH $\left[\frac{(V4 + V5) - (V7 + V8 + V9 + V10 + V11 + V12 + V13)}{V2} \right] \cdot 10^6$

TABLE 8

TRAINING RATE BY COURSE OBJECTIVE CATEGORY

Variable No.	Name
V45	Roof fall employee courses per employee (Category 1) $\frac{V14}{V1}$
V46	Material handling courses per employee (Category 2) $\frac{V15}{V1}$
V47	Haulage employee courses per employee (Category 3) $\frac{V16}{V1}$

TABLE 8 (cont.)

Variable No.	Name
V48	Electrical employee courses per employee (Category 4) $\frac{V17}{V1}$
V49	Explosives employee courses per employee (Category 6) $\frac{V18}{V1}$
V50	Machinery employee courses per employee (Category 7) $\frac{V19}{V1}$
V51	General accident prevention employee courses per employee (Category 8) $\frac{V20}{V1}$
V52	First aid employee courses per employee (Category 9) $\frac{V21}{V1}$
V53	Self rescue/mine rescue employee courses per employee (Category 10) $\frac{V22}{V1}$
V54	Explosive atmosphere detection employee courses per employee (Category 11) $\frac{V23}{V1}$
V55	Non-explosive gas deficiency detection employee courses per employee (Category 12) $\frac{V24}{V1}$

TABLE 8 (cont.)

Variable No.	Name
V56	Safety law employee courses per employee (Category 13) $\frac{V25}{V1}$
V57	Safety/management training employee courses per employee (Category 14) $\frac{V26}{V1}$

DATA ANALYSIS

Annual Data Set Cross-Sectional Analyses

The initial data analysis was based upon the 26 cross plots listed Table 9. Of the six most likely distributions of cases in these plots as indicated below, patterns "C" and "F" were found to be most typical for the sample of mines being studied. Another feature of the observed distributions that made the analyses difficult and less than conclusive with regard to how to make training most effective is the large percentage of mines that lie at or near the origin and along each axis. The number of mines out of the 180 mine sample reporting no MESA training courses is 15 in 1972, 10 in 1973, 15 in the first half of 1974, and 5 over the entire period.

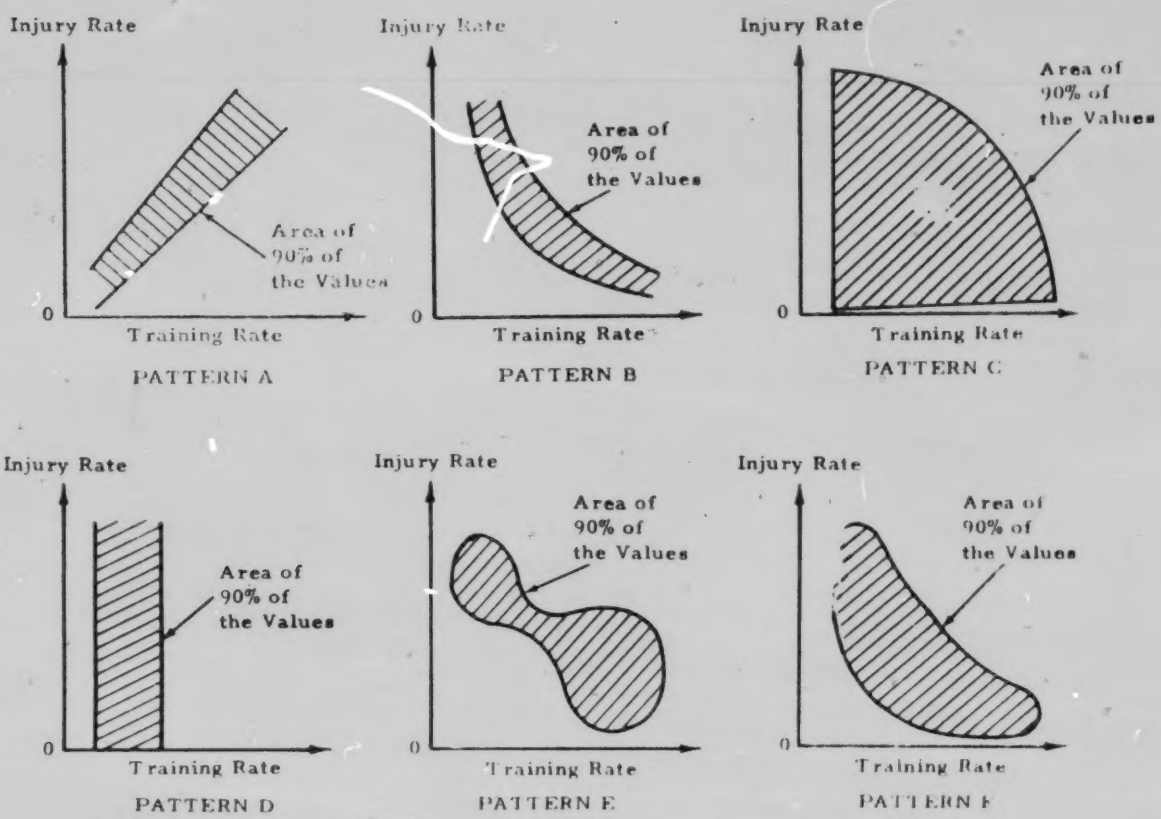


TABLE 9

VARIABLE PLOTS

Plot No.	Base Variable (Vertical Axis) versus Cross Variable (Horizontal Axis)	
1	Roof fall injuries per MMH	Roof fall employee courses/employee
2	Handling materials injuries per MMH	Material handling employee courses/employee
3	Haulage injuries per MMH	Haulage employee courses/employee
4	Electrical injuries per MMH	Electrical employee courses/employee
5	Explsions injuries per MMH	Explosives employee courses/employee
6	Lift/pull injuries per MMH	General accident prevention employee courses/employee
7	Machinery injuries per MMH	Machinery employee courses/employee
8	Roof fall injuries per MMH	General accident prevention employee courses/employee
9	Handling materials injuries per MMH	General accident prevention employee courses/employee
10	Haulage injuries per MMH	General accident prevention employee courses/employee
11	Electrical injuries per MMH	General accident prevention employee courses/employee
12	Explosions injuries per MMH	General accident prevention employee courses/employee
13	Machinery injuries per MMH	General accident prevention employee courses/employee
14	All other injuries per MMH	Explosive atmosphere detection employee courses/ employee
15	Injuries per MMH	First aid employee courses/employee
16	Injuries per MMH	Rescue employee courses/employee
17	Injuries per MMH	Explosive atmosphere detection employee courses/ employee
18	Injuries per MMH	Non-explosive detection employee courses/employee
19	Injuries per MMH	Safety law employee courses/employee
20	Injuries per MMH	Safety/management training employee courses/ employee
21	Injuries per MMH	General accident prevention employee courses/ employee
22	Injuries per MMH	Mine emergency employee courses/employee
23	Injuries per MMH	Total employee courses/employee
24	Average lost days per injury	Mine emergency employee courses/employee
25	Average lost days per injury	Total employee courses/employee
26	Total lost days per thousand tons of production	Employee courses per thousand tons of production

Schematics of the data plots are given in the text for the majority of these cross variable plots. The actual data plots as obtained from the computer are in a monthly report of Phase II work. The first plot discussed is number 24 in Table 9, " total injury rate versus total training rate." Figure 2 is the key to the schematic plot summaries.

Total Injury Rate versus Total Training Rate

The first question is : Has the injury rate decreased?

The schematics indicate for each successive year that injury rates are decreasing for the major portion of the mines. The following tabulation shows that the injury rate for the 180 mine sample has been approximately halved between 1972 and mid-1974:

	Year 1972		1973		1974	
	> 30inj/ MMH	> 80 inj/ MMH	> 30 inj/ MMH	> 80 inj/ MMH	> 30 inj/ MMH	> 80 inj/ MMH
Number of mines having greater than 30 or 80 total injuries per MMH	107	52	80	41	54	20

The second question is: Has the training rate increased?

In the case of the training rate, the median[7] has been determined for each year. The increase occurs steadily from 1972 to 1974. Only one half of the year of 1974 is included for employee courses which means the rate may increase even more by the end of the year.

	1972	1973	1974
Training rate in employee-courses per employee	1.2	1.8	2.4

The fact that the training rate has increased and the injury rate decreased does not necessarily argue that increased training rate leads to

7 The median is the most appropriate measure of central tendency for data which has the non-normal distributions that characterize injury and training rates.

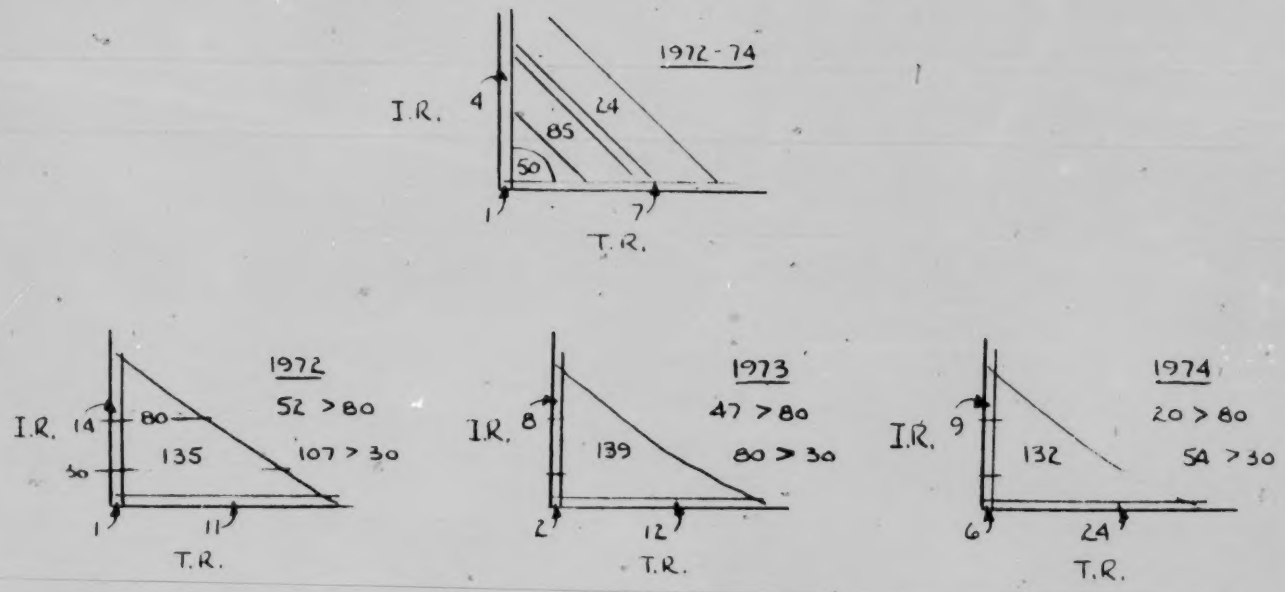


Figure 1

Injury Rate Versus Training Rate

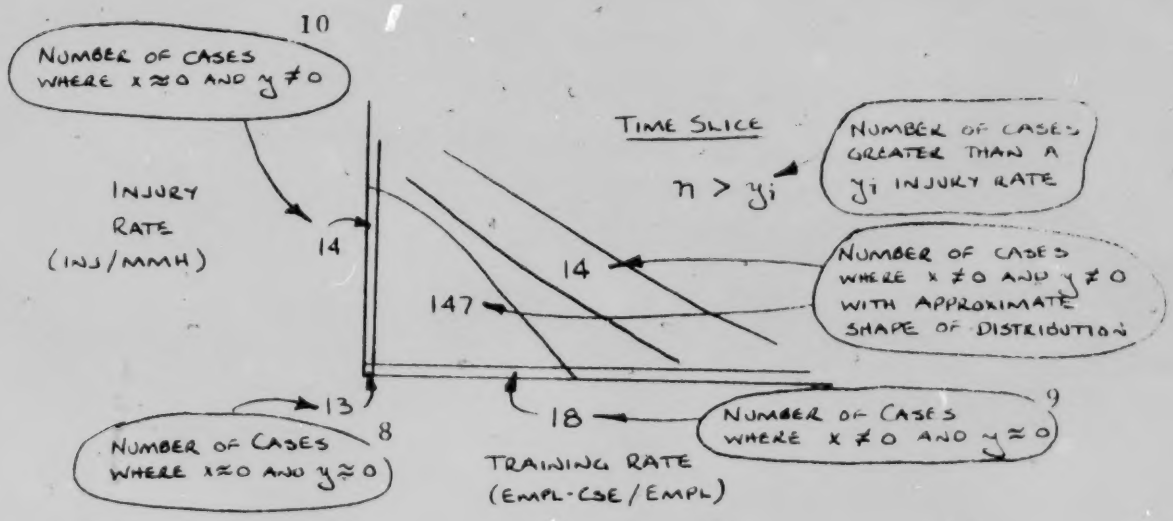

10
NUMBER OF CASES WHERE x ≈ 0 AND y ≠ 0
TIME SLICE
n > yi
NUMBER OF CASES GREATER THAN A yi INJURY RATE
INJURY RATE (INJ/MMH)
14
14
147
NUMBER OF CASES WHERE x ≠ 0 AND y ≠ 0 WITH APPROXIMATE SHAPE OF DISTRIBUTION
13
8
18
9
NUMBER OF CASES WHERE x ≠ 0 AND y ≈ 0
NUMBER OF CASES WHERE x ≈ 0 AND y ≈ 0
TRAINING RATE (EMPL-CSE/EMPL)

Figure 2

Key to Plot Schematics

8 Not actually (0, 0), represents the plot location between 0 and 1/2 the vertical and horizontal intervals.

9 Set between 0 and 1/2 the vertical interval in a horizontal band.

10 Set between 0 and 1/2 the horizontal interval in a vertical band.

a decreased injury rate. Although other causes such as increased federal mine inspections, assessments levied for violations and safer machinery and methods might be put forth, these causes would have to be in turn evaluated and compared to the injury rate in a more complex research design beyond the scope of this project. All of the potential cuases that appear to be associated with training would have to be evaluated by means of multivariate analysis (e.g., discriminate function analysis or regression analysis). Their contribution would be ordered by the amount of variance explained.

One would expect that more than one cause has contributed to the reduced injury rate in coal mining. Not only is lack of experience or training only one of several basic causes, it is also likely that the most important basic cause will vary from one mine to the next. Since the purpose of this project is to understand the relathonship of safety training to accident prevention, instances where a category of training is obviously independent of or detrimental to injury prevention are as useful as those cases having a strong favorable (from the safety trainer's viewpoint) relationship in sorting out the characteristics of training that works from that which does not. The intent of this initial data analysis of a larger sample of mines is to (1) determine the degree of association between various injury causes and training for a cross-section of mines aggregated yearly, and 2) evaluate the effect of emphasis on the substantive categories of training on injury rate.

Examination of the plot in Figure 1 for the total period 1972-74 indicates that training rate and injury rate are not independent because, if they are, the whole quadrant would be filled with data points

As shown in the plot for 1972-74 in Figure 1, the mines tend to group into three clusters. The upper cluster has a higher injury rate for the same amount of training than either of the other two groups. It also has mines in which training might have a more pronounced effect. The group that includes the origin are safe mines that do not do little or no training that is reported to MESA.

Ground Control Training (Category 1)

The number of miners reported as having been trained in MESA course codes AM (Roof and Rib Control) and CV (Job Safety Guide- Roof Bolting Operations) was compared with the number of fatal and non-fatal injuries reported under accident type codes 01 (Fall of Roof), 02 (Pressure

Bump or Burst), and 03 (Fall of Face, Rib, or Side) to determine what relationship, if any, is apparent between this category of training and the injuries the course objectives are aimed at reducing. For the sample of some 170 mines, this category of training consisted of the Roof and Rib Control course exclusively. This is representative of all mines during the first half of 1974 when it was reported for 38,592 miners while course CV was apparently not given at all. Course code AW (Ground Control-Metal and Non-Metal Mines) is also included in training category 1 but was given to only 22 miners during the 1974 period. Although not in the sample of mines included in the plots analyzed one of the four metal-nonmetal mines whose training was reviewed did use course AW some 38 times in 1973. For the coal mines in the sample, category 1 courses represent 11.27 percent of all employee-courses administered for the sample mines during the 1972-1974 period covered by the data as compared with 11.0 percent of all courses for all mines in the first half of 1974. The mines included in the data analyzed are slightly above average with their emphasis on ground control training.

Plots of injury and training rates for these two measures were obtained for the cross section of mines in 1972, 1973, and 1974 (1st half), and the aggregate 1972 through mid-1974 experience. Schematics showing general distribution of points and general trends are illustrated in Figure 3. The number of mines giving a noticeable amount of ground control training increased from 92 to 104 between 1972 and 1973, but falls to 85 for the first half of 1974. As noted earlier, the 1974 mandatory training could have been delayed by many operators in anticipation of the opportunity to conduct training during the strike period. The trend in injuries due to fall of roof or rib, etc. was consistently downward as the number of mines having a rate of more than 9 of these injuries per million man-hours went from 48 to 43 to 26.

From the shape of the plots it can be seen that mines having high injury rates tend to be those giving little or no ground control training. It can also be observed that mines giving this category of training at a high rate have better than average injury rates. Less clear is the large number of cases low on both training and injury rates. Study of how training is conducted at these mines and other characteristics of the mines reveals no common pattern that explains this result. Some of the mines with both low training and low injury rates may simply be lucky, but a more likely answer is that these are mines that have been consistently good in terms of roof and rib, etc., injury rates so that the presence or absence of training can make little difference for them. The extreme cases of high injury or training rates tend to be small mines where one injury or a day of training for all employees will give a very high rate for that year.

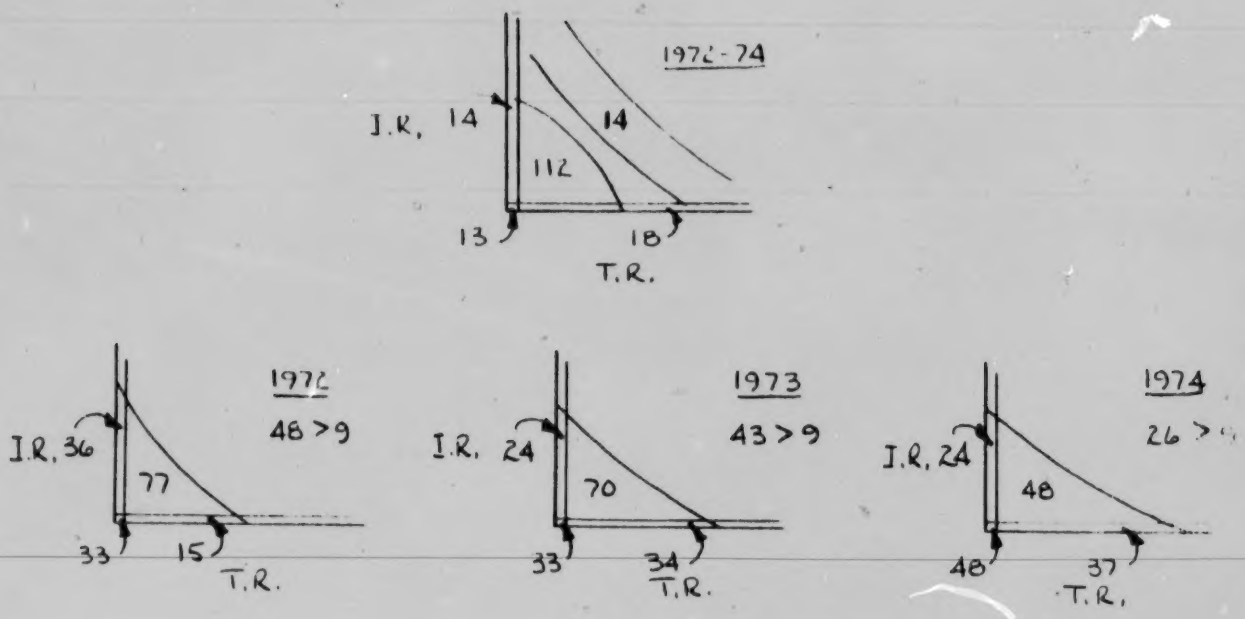


Figure 3

Roof Fall Injury Rate Versus Ground Control Training Rate

Ground Control Courses (Category 1)

Name	Code	'74 Empl-Cse	Requirement
Roof and Rib Control	AM	38,592	C, Q, & A (see note)
Job Safety Guide - Roof Bolting	CV[1]	0	None
Ground Control, Metal & Non-metal	AW	22	None
	Total	38,814	
	Percent of Grand Total[11]	11.0	

11 Grand total of all employee courses in first half '74 is 354,107. Required training for certified (C) & Qualified (Q) persons and All (A) miners require instruction in roof control plan.

Material Handling Training (Category 2)

The number of miners reported as having been trained in MESA course code CH (Materials Storage and Handling) was compared with the number of fatal and non-fatal injuries reported under accident code 07 (Handling Materials) to determine what relationship existed, if any. There is no relationship because the total number of miners taught the course in the cross section of 171 mines was only 19 by one mine in 1973. There were no miners taught course CH in the first six months of 1974.

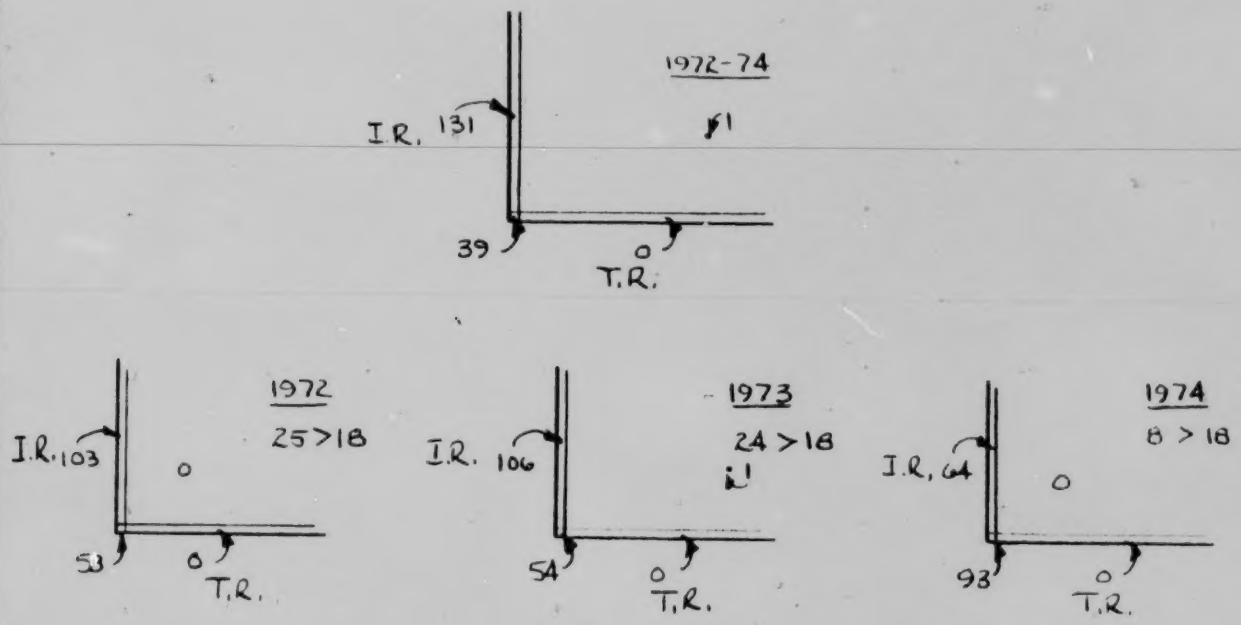


Figure 4

Handling Materials Injury Rate
Versus Materials Handling Training

Material Handling Courses (Category 2)

Name	Code	'74 Empl-Cse	Requirement
Materials Storage and Handling	CH	0	None
	Total	0	
	Percent of Grand Total	0	

Plots of injury and training rates for the cross section of mines for 1972, 1973, 1974 1st half) and total 1972-74 were obtained. The plots illustrated by the schematics of Figure 4 obviously reflect the absence of training here. The trend in injury rate which is independent of training rate, was monotonically downward as the number of mines having a rate of more than 18 injuries per million man-hours went from 25 to 24 to 8. The drop from 24 in 1973 to 8 in 1974 (first half) cannot be associated with the training of the course Materials Storage and Handling.

Haulage Training (Category 3)

The number of miners reported as having been trained in MESA course codes CK (Belt Examiner), CN (Accident Prevention - Haulage) and CW (Job Safety Guide-Shttle Car Operation) was compared with the number of fatal and non-fatal injuries reported under accident code 11 (Haulage) to uncover what relationship, if any, exists between this category of training and the injuries the course objectives are aimed at reducing. In the first half of 1974, 685 miners received the course CK (Belt Examiner) and 1220 the course CN (Accident Prevention-Haulage). Not one miner was given course CW (Job Safety Guide-Shuttle Car Operation). This training constituted 0.5 per cent of the total training for the cross section of the 180 mines from 1972 to 1974.

Cross variable plots of injury and training rates for these two measures were obtained for the 180 mines in 1972, 1973, and 1974 (first half), and the 1972 through mid-1974 aggregate data. The schematics of distribution of points and general trends are sketched in Figure 5. The number of mines giving a noticeable amount of training in haulage safety increased from 18 in 1972 to 40 in 1973. The number of mines was 21 for the first half of 197 , which was greater than all of 1972. The trend in injury rate due to haulage accidents rose from 1972 to 1973 as evidenced by the number of mines having greater than 9 injuries per million man-hours. This number was 38 in 1972 and 41 in 1973. The number of mines dropped to 33 in 1974 with more than 9 injuries per million man-hours.

From the shape of the plots it can be seen that mines giving more of this training tend to have a lower haulage injury rate. Mines giving less training generally have a higher injury rate. As before, this sample of mines includes a large set of mines for which the behavior is unclear. They have little training and negligible injury rate.

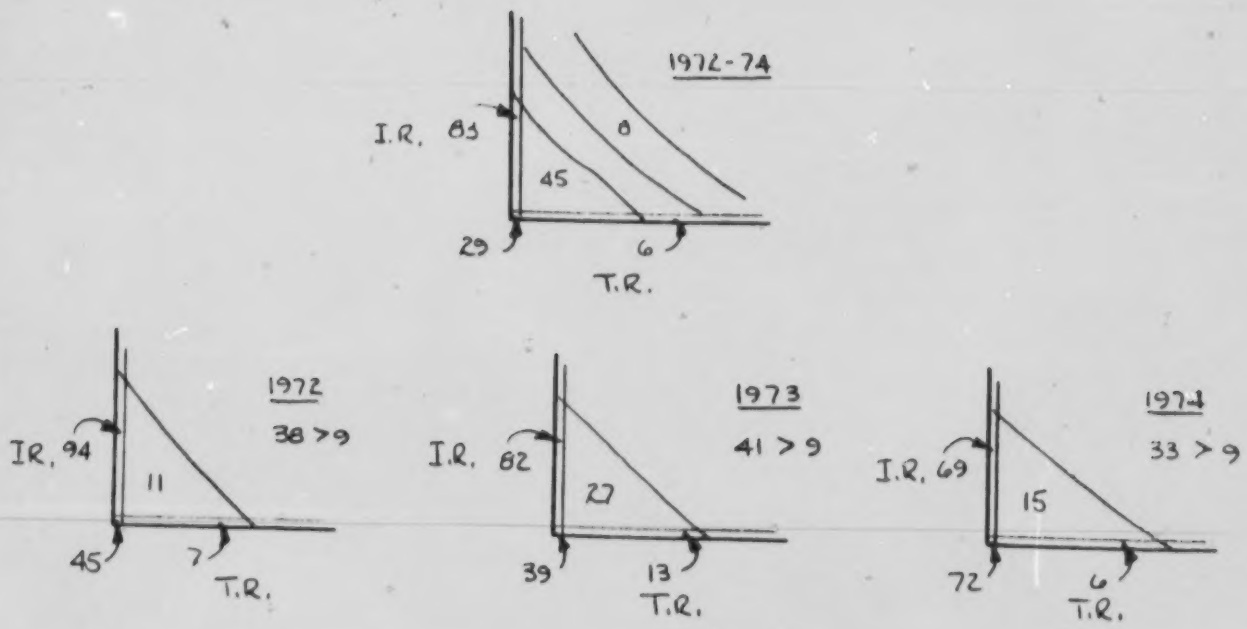


Figure 5

Haulage Injury Rate Versus Haulage Training Rate

Haulage Safety/Accident Prevention Courses (Category 3)

Name	Code	'74 Empl-Cse	Requirement
Belt Examiner	CK	685	None
Accident Prevention-Haulage	CN	1,220	None
Job Safety Guide-Shuttle Car Operation	CW	0	None
	Total	1,905	
	Percent of Grand Total	0.5	

Electricial Training (Category 4)

The number of miners receiving training in the ten courses in Category 4 for all mines in the first half of 1974 are listed in Figure 6. The number of miners taking the course AA (Accident Prevention - Electrical) was 3, 498 while the number taking the electrical qualification and retraining courses was 15, 094 with over half in underground electrical qualification (EB) and retraining courses. The percentage of electrical courses given to miners in the first half of 1974 was 19,402 or 5.5 percent of all employee courses. Similarly, the percentage of all courses in the 1972-74 period for the mines studied was 4.45.

Plots of injury and training rates for these two measures were obtained for the sample of mines in 1972, 1973, and 1974 (first half), and the 1972 through mid-1974 aggregate experience. Schematics for distribution of points and general trends are illustrated in Figure 6. The number of mines giving a noticable amount of electrical training increased markedly from 28 in 1972 to 101 in 1973 and to 110 fro the first half year in 1974. The trend in injury rate for MESA injury type code 14 (Electrical) is consistently down - approximately 30 percent from 1972 to 1973 and 1973 to 1974 (first half). The number of mines with injury rates greater than 3 per million man-hours has fallen from 31 in 1972 to 14 in 1974 (first half).

Again the shape of the curve outlining the data set indicates that mines with more training generally have a lower injury rate. These mines with less training generally have a higher injury rate. Where in 1972 there were 64 mines with an appreciable injury rate there were only 28 mines with an appreciable training rate there were 110 in 1974. There still is the large group of mines with both negligible training and injury rates which are characterized by only a large portion of their number being in large companies having extensive training efforts outside of the MESA reporting system as well as generally better than average records for all aspects of the operation.

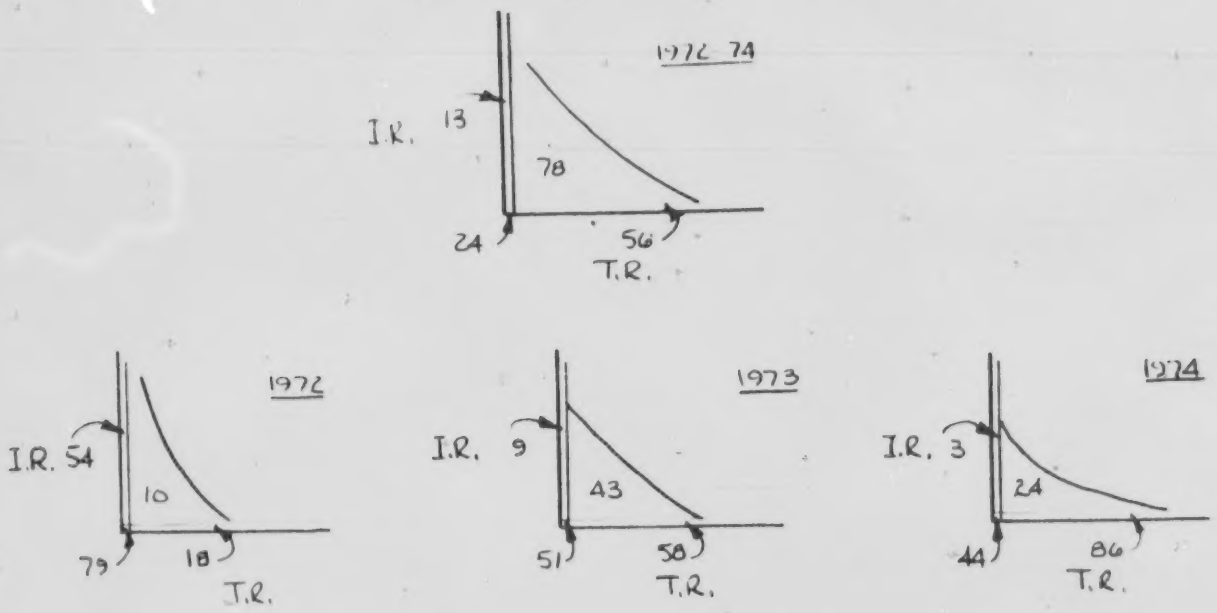


Figure 6

Electrical Injury Rate Versus Electrical Training Rate

Electrical Safety and Qual/Requal Courses (Category 4)

Name	Code	'74 Empl-Case	Requirement
Accident Prevention			
Electrical	AA	3,498	None
Electrical Qulaificantion			
Underground	EB	3,611	Q
Retraining, underground	EC	5,966	Q
Surface	ED	1,579	Q
Retraining, surface	EE	3,810	Q
Underground, Anthracite	EI	0	Q
Retraining, U.G., Anth.	EJ	8	Q
Surface, Anthracite	EK	39	Q
Retraining, surf., Anth.	EL	81	Q
Trailing Cable Splicing	EM	810	None
	Total	19,402	
Percent of Grand Total		5.5	

Explosives Safety and Explosive Atmosphere Detection (Categories 6 and 11)

The number of miners reported as having been trained in the 23 courses in training categories 6 and 11 (Explosives Safety and Explosive atmosphere Detection) was compared with the number of fatal and non-fatal injuries reported uncer accident type codes 12 (Explosion of gas or dust), 13 (Explosive and Breaking Agent), 17 (Mine Fire), and 20 (Ignition of Gas or Dust) to determine what relationship, if any, is apparent between this category of training and injuries the courses are aimed at reducing. The 23 courses are listed in the continuation of Figure 7. Inspection of this list will show that 112,082 miners were taught the use of a device to detect an explosive mine atmosphere in the first half of 1974. This represents 31.6 percent of the total number of courses given in 1974. The number of miners given course code AI (Coal Mine Ventilation) was 24,082 and course code AE (Safe Use and Handling of Explosives) was 3,009. The training is intensive and widespread in this category, accounting for 41.1 percent of the total training given in the first half of 1974. The percentage of total training was 41.8 for the sample of 180 mines for 1972, 1973 and 1974 (first half). This type of injury received the heaviest emphasis in training by far.

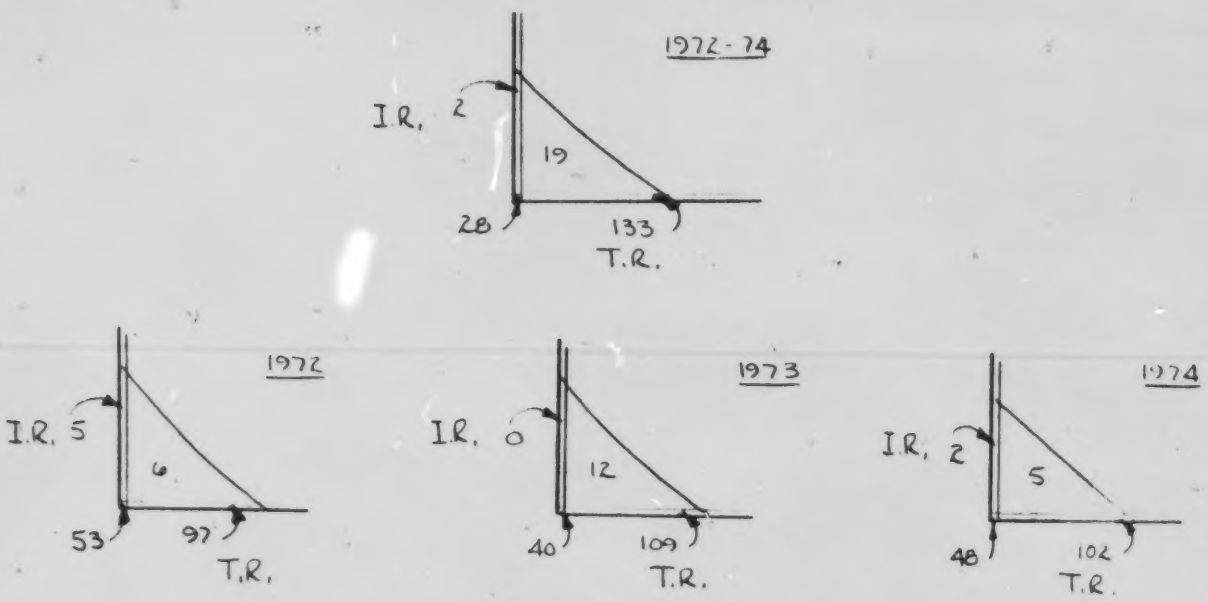


Figure 7

Explosion/Ignition Injury Rate Versus Explosives Safety and Explosive Atmosphere Detection Training

Figure 7 (cont.)

Explosives Safety and Explosive Atmosphere Detection and/or Prevention Courses (Categories 6 and 11)

Name	Code	'74 Empl-Cse	Requirements
Safe Use and Handling of Explosives	AE	3,009	Q
Storage, Handling, and Use of Explosives	CA	418	None
Safe Use of Sensitized Ammonia Nitrate	CF	0	None
Safe Use and Care of Flame Safety Lamps	AF	2,394	C
Flame Safety Lamp	BB	36,623	C & Q
Bacharach Methan Detector	BA	18,503	C & Q
G-70 Methanometer	BC	14,230	C & Q
M-402 Methanometer	BD	9,661	C & Q
MSA Methane Spotter	BE	29,151	C & Q
P-2 Methane Tester	BF	4	C & Q
Riken Methan Detector	BG	3,844	C & Q
W-8 Methane Detector	BH	55	C & Q
J. W. Methane Sniffer	BI	3	C & Q
Mini-Mite Pyrometer	DJ	0	None
MSA Explosimeter	DK	0	None
Draeger Multi-Gas Detector	DM	8	None
Coal Mine Ventilation	AI	24,082	C & Q
Fundementals and Principles of Mine Vent.	AV	63	None
Respirable Coal Mine Dust	CI	753	None
Gravimetric Dust Sampling	CO	3	None
Dust Sampling in Metal/ Non-Metal Mines	CE	0	None
Mine Fires and Explosions	AZ	238	None
Total		143,042	
Percent of Grand Total		40.4	

Plots of injury and training rates for these measures were obtained for the sample of mines in 1972, 1973, and 1974 (first half), and the 1972 through mid-1974 data. A set of schematics showing the distribution of points and general trends is presented in Figure 7. The number of mines giving noticeable explosions/ignitions training increased from 103 in 1972 to 121 in 1973. The number for the first half of 1974 remained relatively high. The number of mines with injuries/million man-hours greater than zero was 11 in 1972, 12 in 1973, and 7 in 1974 (first half). The injury rate was low in 1972 and was reduced even further by 1974.

Because the training rate is so high and the injury rate is so low, it is tempting to argue that training is the cause of the low injury rate. However, the major emphasis upon safety training for explosions and ignitions is due to the past history of this type of injury. When a mine explosion occurs, the injuries are often fatal, and, although the total number is small compared to machinery, haulage, and slip/fall, the severity in lost days per accident is the greatest. The high mandatory emphasis on this safety training is attributable to the notoriety of the injury type, which is often fatal and occurs in bunches. The number of fatal and non-fatal injuries for all coal mines was 130 in 1969 and 172 in 1970. This increase was due to a major lethal accident in 1970. The cumulative number of fatal and non-fatal injures for the cross-section of mines for 1972, 1973 and the first half of 1974 is 245. The totals are roughly comparable for an equivalent period of time and set of mines. The safety training, which was extensive in 1972, has increased slightly. One tentative conclusion is that the safety training was caused by the injury rate which is down to a fairly low level and holding. Sufficient safety training is being given in this category. However, it might be made more effective by a reduction in the number of seperate course codes used for reporting and qualification purposes and an increase of emphasis on the basic objective - detection and elimination of an explosive mine atmosphere.

General Accident Prevention Training (Category 8)

The number of miners receiving training in the 17 courses in Category 8 for all mines in the first half of 1974 are listed at the bottom of Figure 8. The number of miners taking course AD (Elements of the Principles of Accident Prevention) was 632, for the course AG (Fundementals of Accident Prevention for Supervisors) 274, for course AH (Fundementals of Accidents Prevention for Workmen) 514, for course

AJ (Job Safety Analysis) 1,382, for course AL (Principles of Accident Prevention) 413, and for course AO (Strip Mining - Coal) 77. The other eleven courses were not conducted this period. The percentage of accident prevention courses (3,292) of all courses given to miners in the first half of 1974 was 0.9 percent. The percentage of this category of safety training for the 180 mines for 1972, 1973 and the first half of 1974 was 3.67 percent.

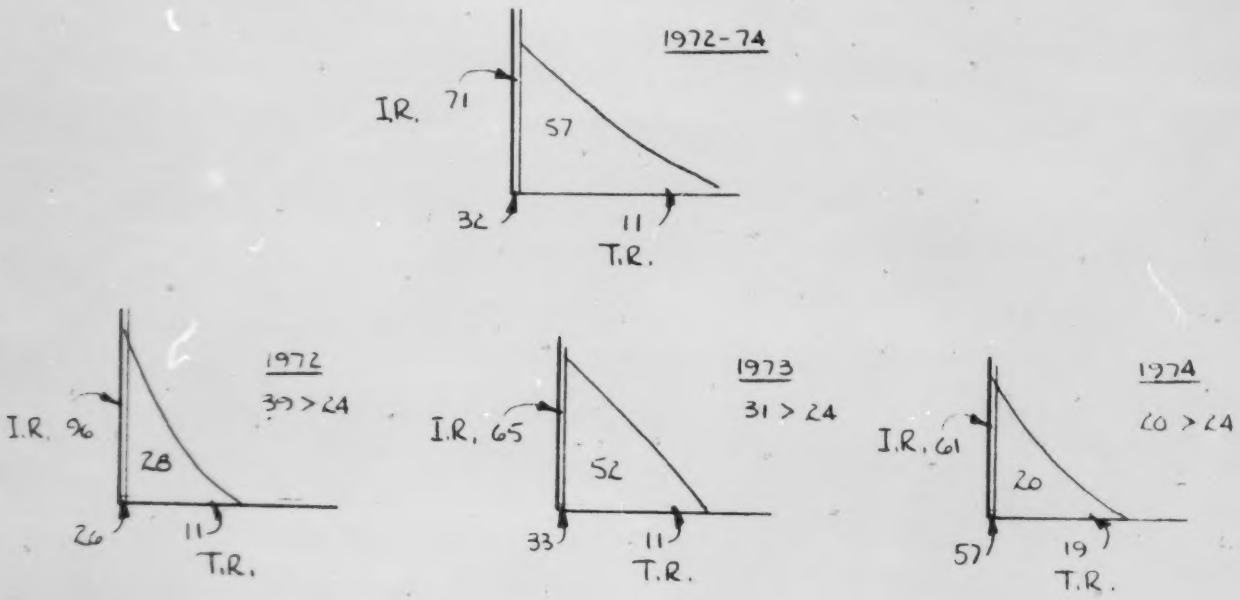


Figure 8

Lift/Pull and Slip/Fall Injury Rate Versus General Accident Prevention Training Rate

Figure 8 (cont.)

General Accident Prevention Courses (Category 8)

Name	Code	'74 Empl-Cse	Requirements
Accident Prevention (A. P.) for Coal Miners	AC	0	None
Elements of the Princ. of A. P.	AD	632	None
Fundementals of A. P. for Supervisors	AG	274	None
Workmen	AH	514	None
Job Safety Analysis	AJ	1, 382	None
Principles of A. P.	AL	413	None
Strip Mining - Coal	AO	77	None
Fundamentals of A. P. for Workmen, metal/non-metal	AS	0	None
A. P. for Metal/non-metal	AT	0	None
A. P. for Petroleum	AY	0	None
Radiation Control and Mining	AX	0	None
Principles of Noise Generation & Control	CJ	0	None
Dynamics of Safety Management	CL	0	None
A. P. for Mining Research Personnel	CS	0	None
Coal Waste Disposal Site Selection	CT	0	None
Noise - Metal/Non-metal	CU	0	None
A. P. for Sand & Gravel	CY	0	None
	Total	3, 292	
	Percent of Grand Total	0.9	

Plots of injury and training rates for lift/pull and slip/fall injury types and the general accident prevention category were obtained for the sample of mines in 1972, 1973, and 1974 (first half), and the 1972 through mid-1974 aggregate experience. The schematics of point distributions and general trends appear in Figure 8. The number of mines giving a noticeable amount of accident prevention training increased from 39 in 1972 to 63 in 1973. The number was down to 39 for the first half of 1974. The trend for injuries for MESA injury codes 06, 09, 10, (Slip/Fall, Stepping or Kneeling on Object, and Striking or Bumping) and 19 (Lift/Pull) decreased consistently from 1972 to 1974. The number of mines with injury rates greater than 24 per million man-hours was 39 in 1972, 31 in 1973 and 20 in 1974 (first half).

Again the shape of the curve outlining the data set indicates that mines with higher than average rates of training have a lower injury rate then mines with less training except for the group of cases that is consistently low for both rates. It is clear that the mines that are sufficiently concerned with safety to train extensively in these optional training courses do have better than average accident records. Although the training contributes to these good records in some way, the most likely interpretation is that the training level is indicative of management attitude and the consequent overall success of all safety measures.

Machinery Training (Category 7)

The total number of miners receiving training in the seven courses in Category 7 for all mines in the first half of 1974 was 185. The break out is listed on Figure 9. Although some courses such as EF (Hoist Engineer Qualification Training - Electric) are directed at a small number of personnel with a limited number of courses administered, a course such as CB (Machine Safeguarding) might be appropriate for more than 30 of the nation's coal miners. The percentage of the 185 employee-courses for machinery training out of all the courses given in the first half of 1974 is 0.05. The percentage was 0.07 for the study sample of mines for 1972, 1973 and 1974 (first half).

Plots of injury and training rates for machinery/hand tool type injuries and this category of training were obtained for the 180 mines in 1972, 1973, and 1974 (first half), and the overall aggregate scores. The distribution of points and general trends are shown in the schematics of Figure 9. In this category the number of mines giving a noticable

amount of training is 2 in 1972, 11 in 1973, and 9 in the first half of 1974. The trend of injury rate for MESA injury type code 08 and 15 (Machinery and Hand Tools) was consistently down from 1972 to 1974. The number of mines with injury rates greater than 18 per million man-hours was 33 in 1972, 29 in 1973, and 18 in 1974 (first half).

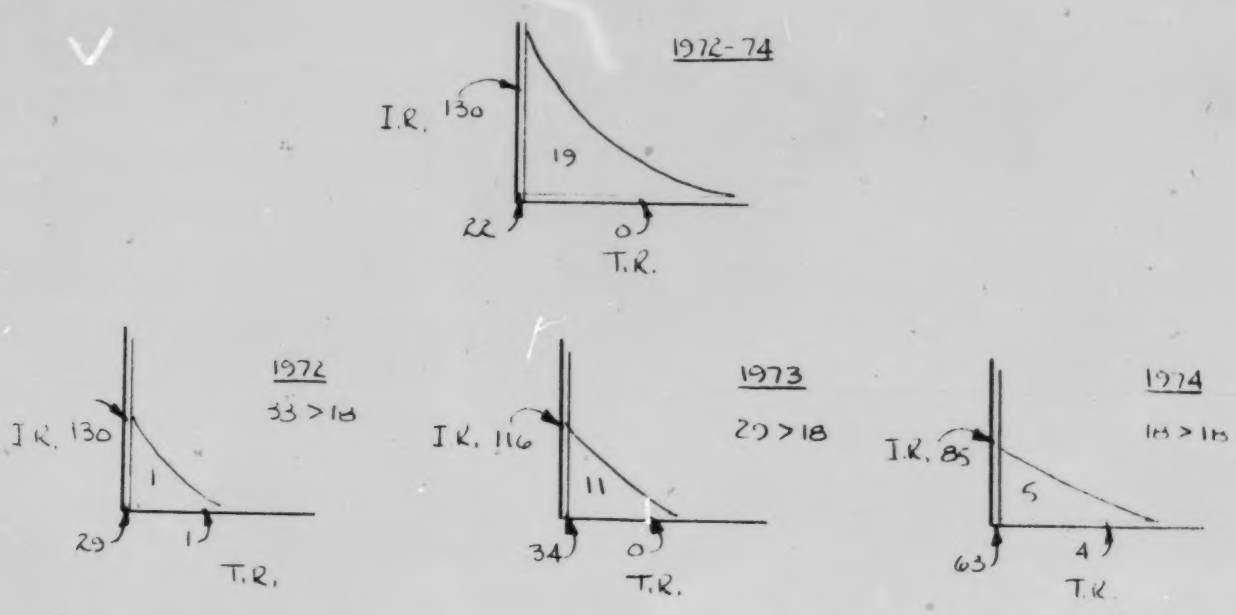


Figure 9

Machinery Injruy Rate Versus Machinery Training Rate

Figure 9 (cont.)

Machniery Safety and/or Qualification Training (Category 7)

Name	Code	'74 Empl-Cse	Requirements
Hoist & Shaft Installation		74	None
Machine Safeguarding		30	None
Safe Use of Diesels Underground		0	None
Job Safety Guide Continuous Miner		0	None
Hoist Engineer Qual. Training			
Electric		25	Q
Steam		0	Q
Surface		56	Q
	Total	185	
	Percent of Grand Total	0.05	

Again the shape of the curve outlining data set (180 mines) indicates that mines giving some machinery safety training have lower injury rates than some of those mines not reporting machinery safety training. However, the number of mines administering a noticeable number of machinery safety training is too few to indicate a relationship.

This and the other six injury categories are summarized in Table 10. The amount of training in both percent of total employee courses and in numbers of mines giving greater than the first data interval of training is compared to two levels of injury rate. Examination of the table indicates that:

- Ground control, explosive atmosphere detection/ explosive safety, and electrical safety are taught more than twice as much as any of the other four categories. This is one grouping.
- General accident prevention and haulage form a second group.
- Machinery and material handling form the third group of little or no training.

TABLE 10

COMPARISON OF INJURY AND TRAINING BY INJURY CAUSE

Training Category / Injury Cause	Percent of Employee-Courses 1-74 to 7-74	Mandatory Courses	Number of Mines Employee-Courses greater than 0+			Number of Mines with Injury Rate greater than[14]					
						1972		1973		1974	
			1972	1973	1974	>0+	>9	>0+	>9	>0+	>9
Roof and Face Fall	11.0	C, Q, A(1)[13]	92	104	85	113	48	94	43	72	26
Handling Materials	0.0	None	0	1	0	103	52	107	48	64	28
Haulage	0.5	None	18	40	21	105	38	109	41	84	33
Electrical	5.5	Q(8)	28	101	110	64	7	52	4	27	2
Explosions/Ignitions and Explosive Atmosphere	41.1	C, Q(11)	103	121	107	11	1	12	2	7	3
Lift/Pull and Slip/Fall (General Accident Prevention)	0.9	None	39	63	39	124	95	117	62	81	46
Machinery	0.05	Q(3)	2	11	9	131	68	127	65	90	43
	59.05[12]										

37

[12] The remaining employee coureses are nondirect injury cause related courses such as first aid, safety laws, etc. The total employee courses was 354,000.

[13] This number in parentheses means that one (1) course is given that has this level of requirement for certification (C), qualification (Q), or all miners (A).

[14] The plus sign is placed upon the zero because the number such as 113 is obtained by subtracting the number in the first interval (0 to 7) from the total. This is often 1.5

- Of the group conducting the greatest amount of training, electrical and explosions are the lowest in injury rate.

- The other two training groups and the roof fall category of the first group combine to form a single group with injury rates greater than twice the electrical and explosions category.

- A finding is that where training is extensive in a category the injury rate is low. The roof fall category has extensive training in one course only (roof and rib control). Where the training is limited or negliglble the injury rate is highest.

- Where safety courses are mandatory, more extensive training is given except for the machinery category in which very little training is apparently required.

- The percentage drop in injury rate is usually greater from 1973 to 1974 than 1972 to 1973.

Non-Specific Safety Training

There is an additional type of safety training that is not aimed at specific injury types. It is divided into five categories as follows:

First Aid Training
Rescue Training
Gas Deficiency Detection Training
Safety Laws Training
Safety Management Training

Table 11 lists the employee-course frequency and a series of figures presents the characteristic plots and other data. Table 12 summarizes the data from these plots and figures. General Accident prevention is also compared to the total injury rate because of the scope of injury types is should reduce. The extensive amount of training in first aid and rescue should contribute to an overall awareness of the

TABLE 11

EMPLOYEE-COURSE FREQUENCY BY COURSE OBJECTIVE CATEGORY- 1/74 TO 7/74

Category and Name of Course	Course Code	Employee-Courses	Requirement
First Aid			
First Aid Methods	FA	23,244	C, A
First Aid Instructions	FB	278	None
First Aid Judges	FC	18	None
First Aid Refresher	FD	20,785	None
Total		44,325	
Percent of Grand Total		12.5	
Rescue			
Use of Self Rescuer	AN	50,453	A
Advanced Rescue and Recovery Operations	MA	5	None
Use of O_2 Breathing Apparatus-McCaa Mouthpiece	MB	54	None
Use of O_2 Breathing Apparatus-McCaa Mouthpiece in Comp. Air	ML	0	None
Use of O_2 Breathing Apparatus-McCaa Facepiece	MD	165	None
Use of O_2 Breathing Apparatus-McCaa Facepiece in Comp. Air	ME	0	None
Use of O_2 Breathing Apparatus-Draeger	MF	139	None
Use of O_2 Breathing Apparatus-Draeger in Comp. Air	MG	0	None
Use of O_2 Breathing Apparatus - Prototen	MH	0	None
Use of O_2 Breathing Apparatus - Prototen in Comp. Air	MI	0	None

TABLE 11 (cont.)

EMPLOYEE-COURSE FREQUENCY BY COURSE OBJECTIVE CATEGORY - 1/74 TO 7/74

Category and Name of Course	Course Code	Employee-Courses	Requirement
Rescue Training Judges	MJ	29	None
Use of Auxiliary Equipment (Chemox)	MK	173	None
Use of Auxiliary Equipment (Demand Type)	ML	0	None
Use of O_2 Breathing Apparatus (Aro)	MM	0	None
Use of O_2 Breath Apparatus	MO	0	None
Principles of Mine Rescue	MP	23,555	C
Rescue Training	MR	297	C
Mine Emergency Training	MS	774	C
Total		75,644	
Percent of Grand Total		21.4	
Miscellaneous Gas Detection			
MSA Colorimeter CO Detector	DA	930	None
Monoxor CO Indicator	DB	207	None
MSA CO Tester	DC	229	None
Fyrite CO_2 Indicator	DD	57	None
MSA H_2S Indicator	DE	412	None
MSA Universal Testing Kit	DF	46	None
MSA NO_2 Detector	DG	28	None
Fyrite O_2 Indicator	DH	57	C, Q
Teledyne O_2 Indicator	DI	0	None
MSA Permissable O_2 Indicator	DL	1,495	C, Q
Total		3,411	
Percent of Grand Total		1.0	
Safety Laws			
Coal Mine Health and Safety Act-Surface Underground)	PA	6,255	None
Coal Mine Health and Safety Act -	PB	11,794	None
Permissable Mining Machinery	PM	2,275	None
Total		20,324	
Percent of Grand Total		5.7	

TABLE 11 (cont.)

EMPLOYEE-COURSE FREQUENCY BY COURSE OBJECTIVE CATEGORY - 1/74 TO 7/74

Category and Name of Course	Course Code	Employee-Courses	Requirement
Safety Programs Management Training			
Coal Mine Supervisors	AB	454	None
Coal Mine Safety Committeeman	AP	0	None
Manager's Safety Techniques	AQ	22	None
Safety Meeting Leadership	AR	154	None
Metal Mine Safety Committeeman	CP	0	None
Audio-Visual Instructor	CQ	8	None
Instructor Training	CR	444	None
Total		1,082	
Percent of Grand Total		0.3	

need to work at safety. If the training is well carried out, it can contribute to the development of an attitude that the operator is concerned with the miner's safety. The only course given extensively is the first aid refresher which must be available to all miners. Some of the 1972-74 schematics indicate that it is likely that overall injury rate is independent of these categories of training with few exceptions. One is general accident prevention (Figure 10) which is compared earlier to lift/pull injury rate and to the handling materials injury rate in the time series analysis. Other training categories were related to total injuries (Figure 12 -- particularly 1972), and safety management (Figure 15). Of note is the fact that total lost days appears to be independent of both overall training rate (Figure 23) and of mine emergency training (Figure 24). Mine emergency training rate is the combination of first aid and rescue training.

Cross plots of general accident prevention training versus injury type categories of explosions and electrical (Figures 19 and 18) seem to show that when training is high the injury rate is low and vice versa. Any number of hypotheses might be offered for this apparent association. Two are:

- The association is due to training in electrical and explosions which are ten times as extensive. The mines that teach accident prevention also teach electrical and explosions.

- The expert electricians do not have the electical type accidents while those receiving general accident prevention are the less skilled who do have accidents.

These two hypotheses are contradictory. The first hypothesis infers that accident prevention is less likely to be the cause of a change in injury rate than the specialized training. The second hypothesis suggests that the accident prevention courses are responsible. In order to obtain the correct hypothesis (if such is possible) additional study of the time series for injuries and training of the individual mines is needed. Before going to the discussion of this work one additional characteristic of the cross-sectional data will be noted.

TABLE 12

COMPARISON OF NON-SPECIFIC TRAINING WITH INJURIES

Training Category	Percent of Employee-Courses 1-74 to 7-74	Mandatory Courses	Number of Mines Employee-Courses greater than 0+			Number of Mines with Injury Rate greater than:					
			1972	1973	1974	1972		1973		1974	
						>30	>80	>30	>80	>30	>80
General Accident Prevention	0.9	None	39	63	39	107	52	80	41	54	20
First Aid	12.5	C & A(1)	132	131	115	107	52	80	41	54	20
Mine Rescue	21.4	C & A(2)	96	133	113	107	52	80	41	54	20
Misc. Gas Detection/Test	1.0	C & Q(2)	12	23	32	107	52	80	41	54	20
Mine Safety Law	5.7	C(2)	76	95	79	107	52	80	41	54	20
Safety Program Management	0.3	None	3	43	24	107	52	80	41	54	20

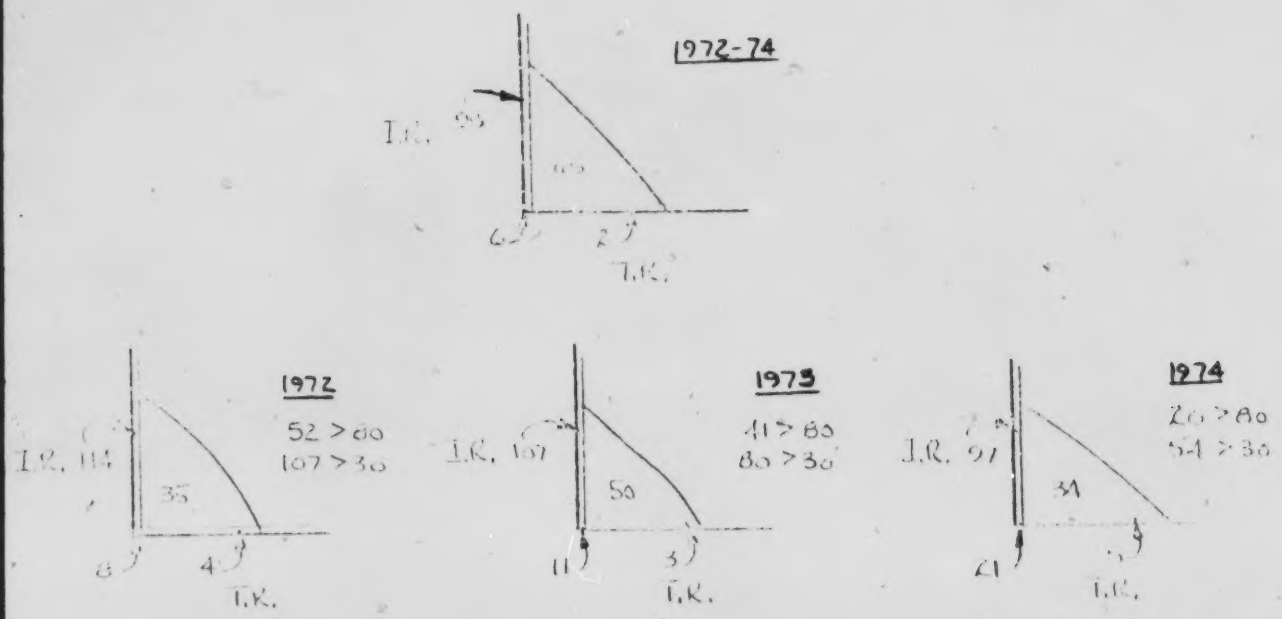


Figure 10

Total Injury Rate Versus
General Accident Prevention Training Rate

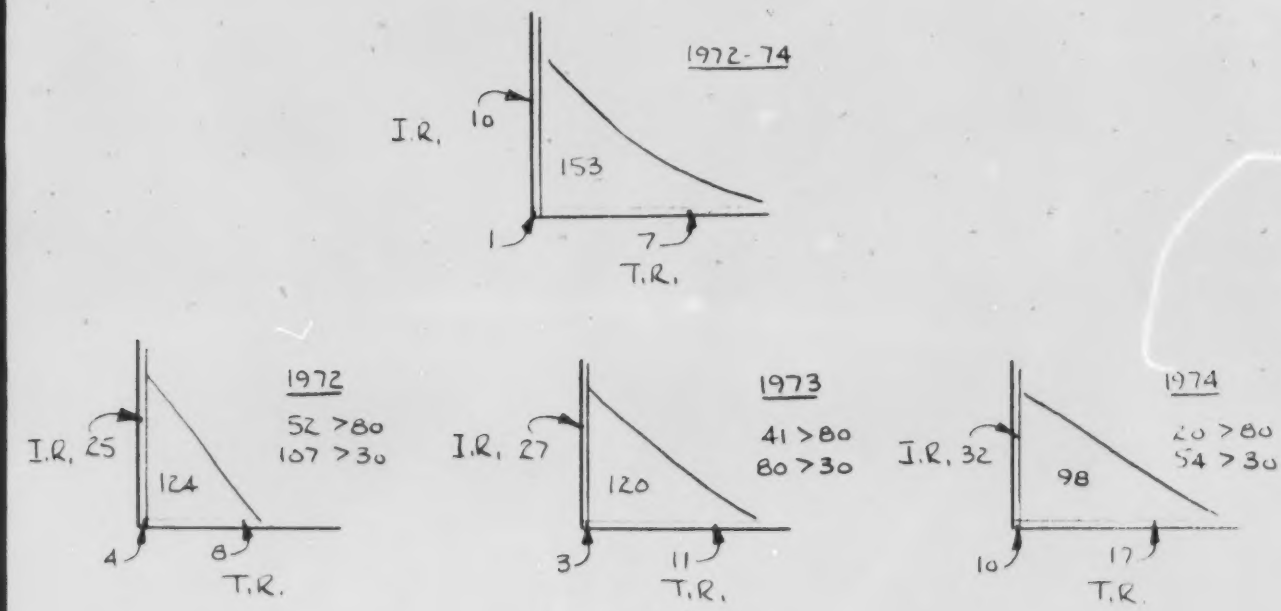
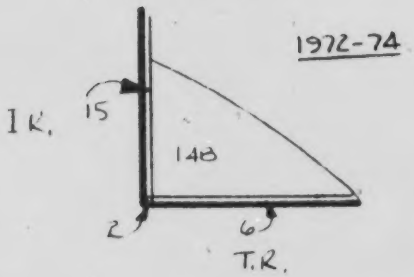
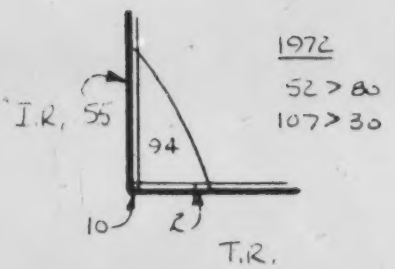
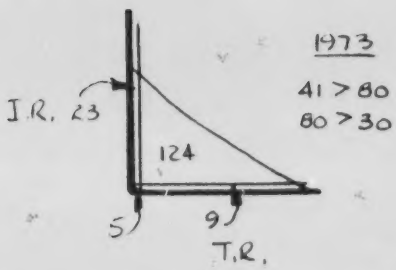


Figure 11

Total Injury Rate Versus
First Aid Training Rate







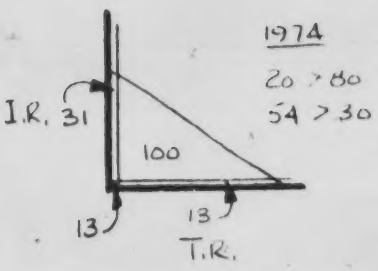
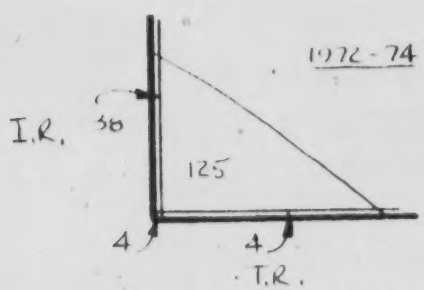
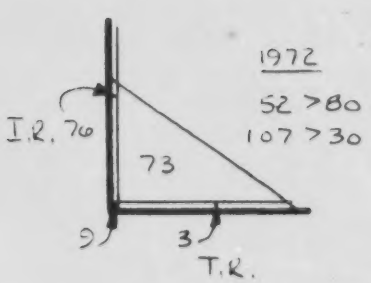
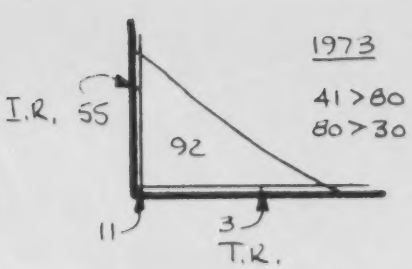


Figure 12

Total Injury Rate Versus
Mine Rescue Training Rate







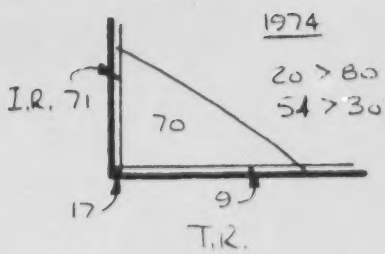


Figure 13

Total Injury Rate Versus
Mine Safety Law Training Rate

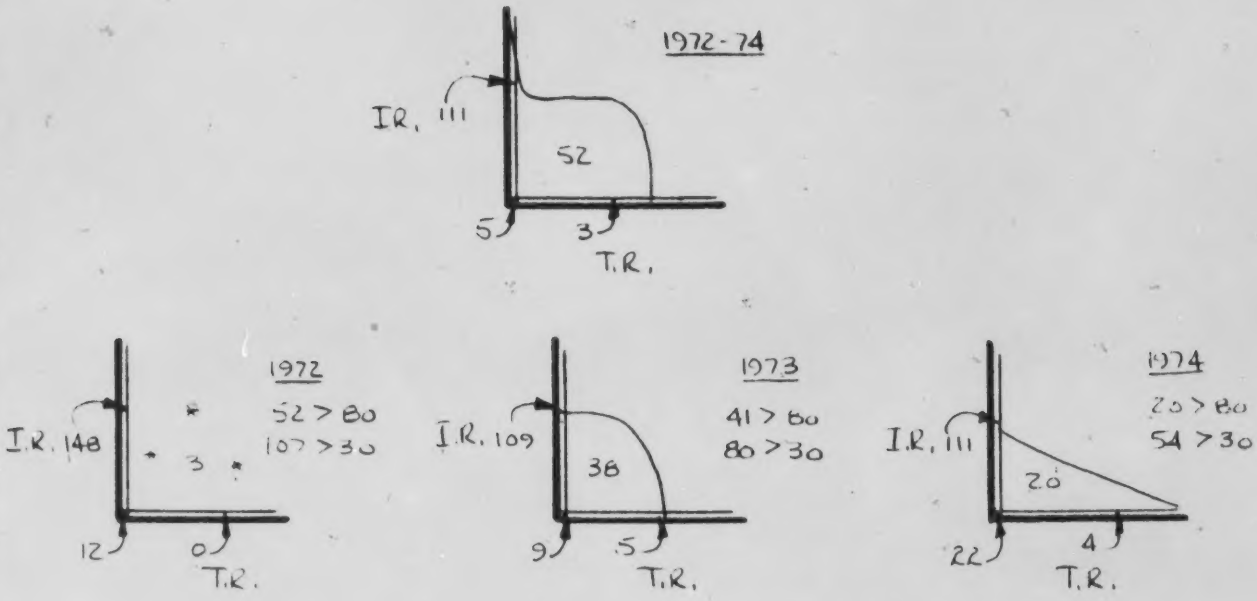


Figure 14

Total Injury Rate Versus
Safety Program Management Training Rate

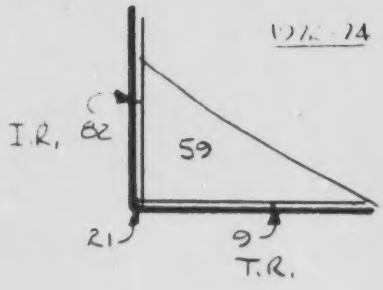


Figure 15

Roof and Rib Fall Injury
Rate Versus General
Accident Prevention
Training Rate

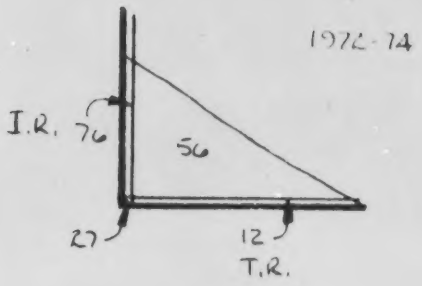


Figure 16

Handling Materials Injury
Rate Versus General
Accident Prevention
Training Rate

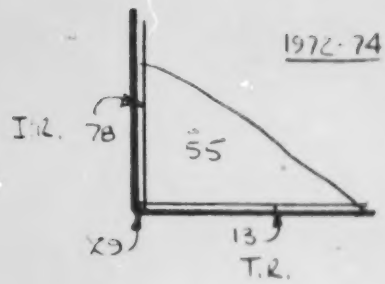


Figure 17

Haulage Injury
Rate Versus General
Accident Prevention
Training Rate

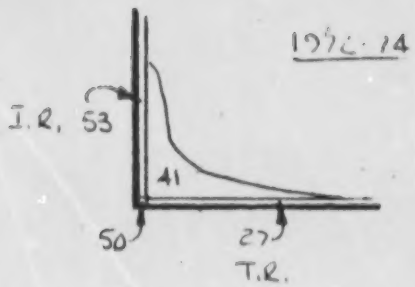


Figure 18

Electrical Injury
Rate Versus General
Accident Prevention
Training Rate

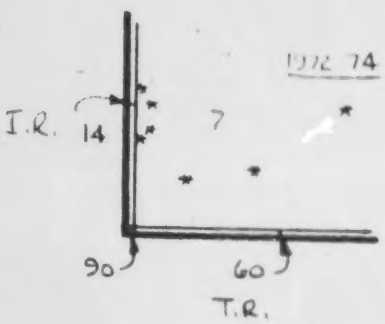


Figure 19

Explosion/Ignition Injury
Rate Versus General
Accident Prevention
Training Rate

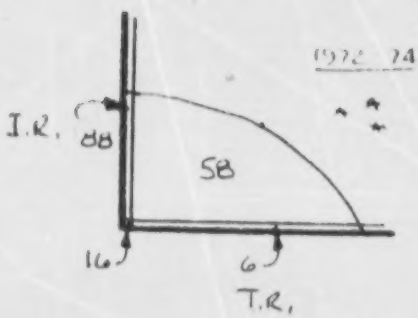


Figure 20

Machinery Injury
Rate Versus General
Accident Prevention
Training Rate

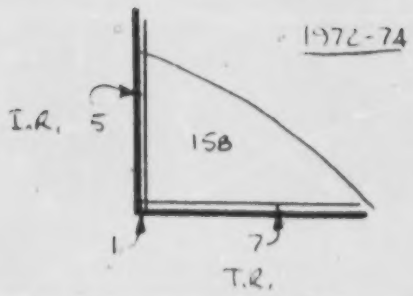


Figure 21

Total Injury Rate
Versus Mine Emergency
Training Rate

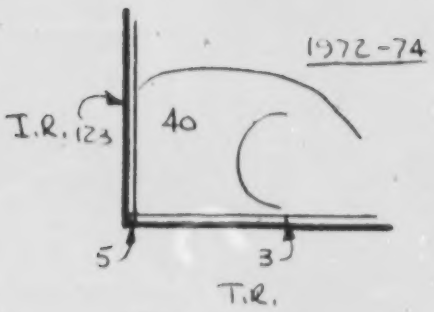


Figure 22

Total Injury Rate
Miscellaneous Gas Detection
Training Rate

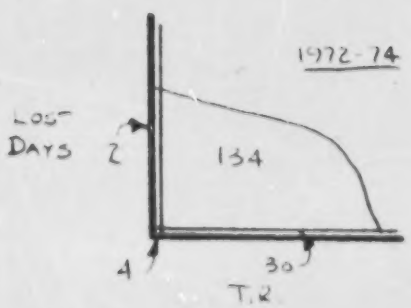


Figure 23

Total Lost Days
Versus Total
Training Rate

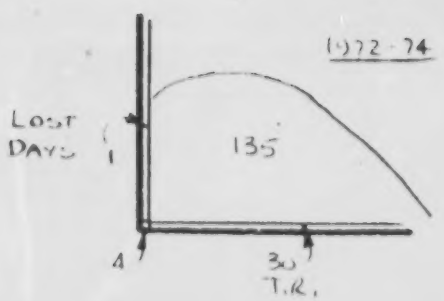


Figure 24

Total Lost Days
Versus Mine Emergency
Training Rate

Training Emphasis and Injury Comparisons

An aggregation of training and injuries of 182 mines for 1972, 1973 and the 6 months of 1974 was also made. Table 13 summarizes the data and is the basis for the following discussion.

The first comparison is between the amount of training in employee-courses for the 182 coal mines used in the Bendix sample and all the coal mining operations reporting their training in 1974. There are only two differences of note in the samples. General accident prevention is 3.67 percent for the Bendix sample and only 0.9 percent for the all mine 1974 sample. The other difference is in first aid training: 9.79 percent to 12.5 percent, respectively. The smallness of these and the remaining differences suggests that the two aggregates are quite similar.

The comparison of primary interest here is between the level of training and the injury level. On the one hand there is relatively little training recorded in handling materials, haulage, and machinery safety categories. The injury level, on the other hand, is 13.8, 12.50, 19.67 percent, respectively. These injury types are three of the five highest in injuries and taught the least.

The primary cause of injuries (slip/fall and lift/pull at 27.53 percent) receives less than four percent of the training effort recorded. Although technical training comes to only 1 percent less training than slip/fall, its injury total is only 0.5 percent compared to 27.53 percent over 40% of the training effort is expended on explosions/ignitions. The injury level is only 2.9 percent of the total. The only training that appears to be at all balanced to the injury cause level is ground control at 11.27 to 14.47 percent.

Explosions/Ignitions and electrical are very strongly emphasized while machinery, haulage, handling materials and general accident prevention are emphasized very little, both in terms of requirement and practice. Ground control may not be emphasized quite enough.

One technique for increasing emphasis is to make courses mandatory wihtin the appropriate categories. In one instance, machinery courses are mandatory category but do not amount to a sizeable portion of total training. Thses mandatory courses are for training engineers in the safe operation of the hoist. There are not many personnel required to take the courses. In the case of steam hoist training no courses are given because steam hoists are no longer used. Other machinery courses might be made mandatory, such as Machine Safeguarding and Job Safety Guidance Continuous Miner. Indeed, the terms of the latest agreement between the BCOA and UMWA and proposed regulations for the training and retraining of miners will bring about such a change in emphasis.

TABLE 13

DISTRIBUTION OF TRAINING EFFORT AND INJURIES

Type of Training and Injury Cause	Training All Mines 1974 (6 months) Percent	Training 180 Mines[15] 1972-74 Percent	Injuries 180 Mines 1972-1974 Number	Injuries 180 Mines 1972-1974 Percent
Ground Control (Roof & Face Fall)	11.0	11.27	1210	14.47
Handling Materials	0.0	0.01	1154	13.80
Haulage	0.5	0.55	1046	12.50
Explosions/Ignitions and Explosive Atmosphere Testing	41.1	41.8	245	2.93
Electrical	5.5	4.45	43	0.51
General Accident Prev. (Slip/Fall)	0.9	3.67	2303	27.53
Machinery	0.05	0.07	1645	19.67
Total by Cause	59.05	61.83	7646	91.40
All Other Injuries			719	8.60
Total Injuries			8365	100
First Aid	12.5	9.79		
Rescue	21.4	22.13		
Misc. Gas Detection	1.0	0.87		
Mine Safety Law	5.7	4.96		
Safety Management	0.3	0.41		
Total Non-Specific	40.9	38.15		
Grand Total	99.95	99.98		

[15] Total employee-courses for 180 mine sample 1972-74 is 43,679.

Quarterly Data Set Time Series Analyses

Introduction

Two additional examinations of the relationships between various categories of training and types of injuries were carried out to complete and strengthen the results of cross-sectional analyses reported here. Both the annual and quarterly MESA data were analyzed as a time series in order to better derive causal inferences.

The time series analysis of the MESA annual data could not yield strong indication of causality in any of the relationships because the number of periods is too small and the agregation of the quarterly data into annual data removes information. Selective consideration of the cases indicates that an increase of training subsequent to high or increased injury rates is not as likely to be associated with a concurrent or subsequent reduced injury rate as the training that was consistently above average in rate in all three years.

The only difference between the annual and quarterly data is the time period of the aggregation. The annual data is simply an average over four or two periods of the quarterly data. In this study the data for ten quarters (first quarter 1972 through the second quarter of 1974) eight comparisons of the parametric time series of injury and training categories were carried out as indicated in Table 14.

TABLE 14

TIME SERIES COMPARISONS

Injuries/MMH	Employee Courses/MMH
Haulage	Haulage
Roof & Face Fall	Ground Control
Handling Materials	General Accident Prevention
Machinery	Machinery
Electrical	Electrical
Lift/Pull and Slip/Fall	General Accident Prevention
Explosions/Ignitions	Explosions Safety and Explosive Atmospheric Detection
All Injuries	General Accident Prevention

The approximately 180 mine parametric time series for each injury/training category are sorted as to injuries only, training only, neither injuries nor training, and both injuries and training. These are presented in Table 15.

TABLE 15

COMMONALITY OF INJURIES AND TRAINING

	Number of Mines Having:			
Injury vs. Training	Injuries & Training	Injuries Only	Training Only	Neither
Haulage vs. Haulage	53	79	7	37
Roof & Face Fall vs. Ground Control	131	9	21	20
Handling Materials vs. General Accident Prevention	102	33	24	22
Machinery vs. Machinery	22	131	0	28
Electrical vs. Electrical	77	14	65	23
Lift/Pull & Slip/Fall vs. General Accident Prevention	115	39	13	14
Explosions/Ignitions vs. Explosives Safety & Explosive Atmospheric Detection	24	1	146	9
All Injuries vs. General Accident Prevention	126	47	1	6

The data of primary interest is that for which both injuries and training occur in the mine during the period. Since there are 10 quarters in the data set and two variables, the number of data points considered is obtained by multiplying the entries in the injuries and training column by 20. Thus 2300 data points are evaluated when studying the two time parametric injury and training series. This manual count supports

earlier findings in training emphasis. The relationship of injuries only to training only indicates that much training is given in explosions/ignitions and explosive atmosphere detection, for example, and not enough in haulage.

Another characteristic of these data sets is that injuries occurred earlier in the time series than training more frequently than after training or in the same quarter. One exception is the explosion/ignition type of injury. Injuries leading to training is statistically significant for these data sets.

The question of fundamental importance is whether training is followed by a reduced injury rate more often than not. If this is demonstrated with statistical significance, comparisons of small sets of effective and ineffective mines will be more meaningful because they are drawn from a larger statistically significant population. Of equal importance is that ratios of effective training quarters to total training quarters yeilds significant expected values of effective training.

The criteria of effectiveness in relating the time series measures of injury and training rates should be conservative, be sufficiently proscriptive to remove subjectivity,[16] and be simple enough to permit rapid evaluation: The possible evaluation choices are effective, random, ineffective, unclear, and independent. These ratings are defined as follows:

Independent - When injuries and training are separated by two or more quarters

Unclear - Quarters 1 and 10 are sometimes unclear because the previous (1) and following (10) quarters respectively are not available. The values in the two quarters external to the data set can produce different ratings:

16 The subjectivity should be vested in the selection of the criteria and not in their application. Thus discription of the criteria displays any subjectivity or bias.

Effective- When training in any quarter (TR_i) reduces or eliminates in the same quarter (IR_i) and the following quarter (IR_{i+1}) or in the two quarters following T_i.
Thus, when:

$$IR_{i+2} \leq IR_{i+1} < IR_i, \text{ or}$$

$$IR_{i+1} \leq IR_i < IR_{i-1}$$

the training TR_i is evaluated as being effective.

Ineffective- In a similar fashion for TR_i, when:

$$IR_{i+2} > IR_{i+1} > IR_i, \text{ or}$$

$$IR_{i+1} > IR_i > IR_{i-1}$$

the training is evaluated ineffective.

Random- When the quarterly rates alternate in increase and decrease or vice versa, the evaluation is called random because this is the highest expected variation. Thus, when:

$$IR_{i+2} > IR_{i+1} < IR_i,$$

$$IR_{i+2} < IR_{i+1} > IR_i,$$

$$IR_{i+1} < IR_i > IR_{i-1}, \text{ and}$$

$$IR_{i+1} > IR_i < IR_{i-1}$$

are random.

The criteria of effectiveness is at least two successive reductions to the injury rate.[17] Ineffective (counter productive) is at least two successive increases in the injury rate. Two examples are presented in Table 16.

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17 Only in one instance in the examination of all the quarterly data did two identical non-zero values occur successively. Two successive zeros are considered effective training.

TABLE 16

EXAMPLES OF EFFECTIVE AND INEFFECTIVE TRAINING

Roof and Rib Fall Injuries Versus Ground Control Training

Mine A

Period		Injuries/MMH	Training/MMH	Rating
1	(1-72)	7.59	0.00	-----
2	(2-72)	17.61	255.40	Effective
3	(3-72)	15.67	15.67	Effective
4	(4-72)	13.66	95.60	Effective
5	(1-73)	0.00	0.00	-----
6	(2-73)	14.40	14.40	Effective
7	(3-73)	13.71	904.96	Effective
8	(4-73)	13.01	670.05	Effective
9	(1-74)	0.00	164.11	Unclear
10	(2-74)	6.24	112.40	Unclear

Mine B

Period		Injuries/MMH	Training/MMH	Rating
1	(1-72)	2.63	0.00	-----
2	(2-72)	13.97	0.00	-----
3	(3-73)	26.27	96.34	Random
4	(4-73)	8.46	177.75	Random
5	(1-73)	23.39	0.00	-----
6	(2-73)	6.38	0.00	-----
7	(3-73)	6.38	41.50	Ineffective
8	(4-73)	14.82	80.01	Ineffective
9	(1-74)	15.59	245.58	Ineffective
10	(2-74)	36.95	13.44	Unclear

Mine A is an example of effective results from training during periods T_2, T_3, T_4, T_6, T_7, and T_8. The first three are effective because:

Mine A --

T_2: $IR_4 < IR_3 < IR_2$

T_3: Either
$IR_4 < IR_3 < IR_2$,
or
$IR_5 < IR_4 < IR_3$

T_4: $IR_5 < IR_4 < IR_3$

Note that if $IR_{11} > IR_{10}$, then TR_9 and TR_{10} are ineffective since $IR_{11} > IR_{10} > IR_9$. On the other hand, if $IR_{11} < IR_{10}$, then IR_9 would be random because $IR_{11} < IR_{10} > IR_9$. IR_{10} would remain unclear.

Demonstration of the random and ineffective ratings of Mine B[18] can be worked out in the same way.

The validity of comparing the change of IR_i and IR_{i-1} when causality is sought is that the training could have occurred in the first week, month or half of the quarter and reduced the injury rate in the same quarter.

The two time series were compared by this scheme for all the mines containing both injuries and training. The results are shown on Table 17 under the columns marked actual. Random, independent and unclear are combined because these represent training quarters in which effectiveness or counterproductiveness cannot be determined. The columns marked theory represent a completely random relationship. With true randomness the injuries can increase or decrease equally from one quarter to the next. However, when comparing three successive quarters the chance of alternating increases or decreases is twice either successive increases or successive decreases. This is can be illustrated as follows:

TR_1: $IR_2 < IR_3 < IR_4$, P 0.25

TR_1: $IR_2 < IR_3 > IR_4$, P 0.50

TR_1: $IR_2 > IR_3 < IR_4$,

TR_1: $IR_2 > IR_3 > IR_4$, P 0.25

18 Mines A & B are actual cases. Many others are in the data.

TABLE 17

STATISTICAL SIGNIFICANCE OF TRAINING EFFECTS ON INJURY RATES BY CATEGORY

Course Category vs. Injury Type	Total number of Training Quarters	Number of Effective Quarters		Number of Random, Independent &		Number of Ineffective Quarters		Hypothesis Not Random Statistical Significance
		Theory	Actual	Theory	Actual	Theory	Actual	
Haulage vs. Haulage	101	25	39	50	56	25	6	> 99.5
Ground Control vs. Roof and Face Fall	459	115	138	230	290	115	31	> 99.5
General Accident Prevention vs. Handling Materials	265	66	75	132	169	66	21	> 99.5
Machinery vs. Machinery	29	7	8	15	19	7	2	> 90
Electrical vs. Electrical	237	59	60	118	168	59	9	> 99.5
General Accident Prevention vs. Lift/Pull and Slip/Fall	308	77	94	154	169	77	43	> 99.5
Explosives Safety & Explosive Atmosphere Detection vs. Explosions/Ignitions	103	26	26	52	74	26	3	> 99.5
General Accident Prevention vs. All Injuries	320	80	109	160	161	80	50	> 99.5
Injuries only (control) General Accident Prevention vs. All Injuries	320	80	82	160	167	80	71	Random

Findings

The numbers of actual and theoretical (random) training quarters for each time series comparison indicate that there are (for all except explosions and ignitions) more effective quarters than would be expected on a random basis. In all cases there are more in the combined category in actuality than would be expected for random alone. This can be attributed in part to the addition of unclear and independent ratings to this category. In the case of counterproductive the actual are far less than expected for a random relationship. The statistical test of the hypothesis that the data is non-random turned out to be highly significa[redacted] non-randomness. Finding more effective training quarters and [redacted] ineffective cases than expected from random outcomes means that train[redacted] is effective in a causal sense because the evaluation looks at subsequent injury rates.

It might be questioned if the improvement is actually in training in spite of the results of this test. This is verified by performing the same analysis for the set of mines in which no training was given. The injury with training versus injury without training control selected is all injuries in mines in which general accident prevention training was or was not given. General accident prevention is the broadest type of training. The injuries occurred in a random pattern in the control cases.

The criterion of effectiveness in which at least two successive quarters of decrease in injury rate occur for a quarter of training is considered conservative. Less conservative criteria are the [redacted] frequency of injury rate decreases compared to increases and two successive quarters of injury rate less than the quarter in which the injury rate is the beginning point of the sequence.

The appeal to direction of change - up or down - in injury rate is an important measure even though the average of the particular mine injury rate is higher than the industry average. Improvement after training is an important measure. The expected value for effective training (two successive decreases in injury rate) can be obtained from Table 17 by dividing the number of effective quarters by the total number of training quarters. Thus a quarter of haulage training is expected to improve safety following approximately forty percent of the number of quarters given. Similarly, the injury rate is expected to increase in only six percent of the two quarters after training is given. Table 18 is a summary of these percentages of effectiveness, and counterproductive training quarters.

TABLE 18

EXPECTATIONS FOR TRAINING OUTCOMES

Course Category & Injury Type	Total Number of Training Quarters	Approximate Percentages Effective	Independent, Unclear, Random	Counter-Productive
Haulage vs. Haulage	101	39	55	6
Rib & Roof Control vs. Roof & Face Fall	459	30	67	3
General Accident Prevention vs. Handling Materials	265	28	64	8
Machinery vs. Machinery	29	28	65	7
Electrical vs. Electrical	237	25	71	4
General Accident Prevention vs. Lift/Pull and Slip/Fall	308	31	55	14
Explosions/Ignitions vs. Explosions/ Ignitions	103	25	72	3
General Accident Prevention vs. All Injuries	320	34	50	16

These percentages represent the expected statistical values when applying these criteria. Randomly the results would be 25 percent effective and it might be argued that the improvement is slight. The argument is similar to weather forecasting. We can say there will be precipitation 50 percent of the time without knowing the frequency over a year. We could be in large error. If we took the frequency count and it was

60 percent for rain then forecasting rain 60 percent of the time would improve our chances. If we understood the cyclical nature of precipitation (80 percent in winter and spring and 40 percent in summer and fall), we could improve our percentage even more. Weather forecasters do not use this technique - they predict on the basis of knowledge of weather patterns and only in part on climatological data. Our problem is analogous. The purely random weather forecast (50/50; rain/no rain) is like the random increase/decrease of injury rate (25 effective, 50 independent or random, 25 counter effective). In the case of training the need to say which quarter will be effective is not necessary, however, as it is in weather forecasting. The desire is to increase the number of effective training quarters and therefore there is an interest in understanding why some training quarters are effective as in MINE A, Table 16, and ineffective (unproductive) as in MINE B, Table 16.

In summary, we have shown causally that training reduces injury rate and that the expected value of effective training varies from 0.25 to 0.39 for the various types. Equally important, counterproductive training varies in expected value from 0.03 to 0.14 for the various training categories.

Significance Tests

If training and injuries are independent the following hypothesis will hold for the data set. In terms of the question of which comes first for this data set, the following theoretical probabilities exist.

When injuries occur in the first quarter, the random chance of training occurring is one in ten for a pair of time series of ten quarters. The random chance for training to lead is zero because it will be in phase if it occurs in the first quarter and lag in any subsequent quarter. This analysis is completed for each subsequent quarter and the results shown in Table 19.

TABLE 19

RANDOM PROBABILITIES OF INJURIES OR TRAINING LEADING

Probabilities

	Injury Leads (IL)	In Phase (Iϕ)	Training Leads (TL)
1	.9	0.1	0
2	.8	0.1	.1
3	.7	0.1	.2
4	.6	0.1	.3
5	.5	0.1	.4
6	.4	0.1	.5
7	.3	0.1	.6
8	.2	0.1	.7
9	.1	0.1	.8
10	0	0.1	.9
	4.5	1.0	4.5

$$P_{IL} = \frac{4.5}{10} = 0.45 \qquad P_{I\phi} = \frac{1.0}{10} = 0.1 \qquad P_{TL} = \frac{4.5}{10} = 0.45$$

The equations of calculation are:

$$(1)\quad P_T = P_{IL} + P_{I\phi} + P_{TL} = 1.0$$

$$(2)\quad P_{I\phi} = \frac{1}{n}\sum_{i=1}^{n} P_{I\phi_i} = 0.1$$

$$P_{I\phi_i} = P_{I\phi_{i-n}} \quad P_{I\phi_{i+n}}$$

when n = 10

Because of symmetry:

$$(3)\quad P_{IL} = P_{TL}$$

Solving for P_{IL} also yields P_{TL}

$$(4)\quad P_{IL} \quad \frac{1}{n}\sum_{i=1}^{n}\left[\,1.0 - \frac{(n-1)}{n} - P_{I\phi_i}\right]$$

$$= \frac{1}{10}\sum_{1}^{10}\left[\,0.9 - \frac{(n-1)}{n}\right. = 0.45$$

Thus our hypothesis is that for a random lead of training or injuries, training should lead 45 times in one hundred, injuries will lead 45 times in one hundred and they will be in phase 10 times in one hundred.

TABLE 20

FREQUENCY OF INJURIES OR TRAINING LEADING

Injuries vs. Training	Injuries Lead		Training Leads		In Phase		Total
	Random	Actual	Random	Actual	Random	Actual	
Haulage vs. Haulage A/P	24	46	24	6	5	1	53
Roof and Rib Control vs. Roof and Rib Control	59	73	59	38	13	20	131
Handling Materials vs. General Accident Prevention	46	57	46	25	10	20	102
Machinery vs. Machiner	10	21	10	1	2	0	22
Electrical vs. Electrical	35	53	35	14	7	10	77
Lift/Puil and Slip/Fall vs. General Accident Prevention	52	76	52	21	11	18	115
Ignitions/Explosions vs. Explosives Safety and Explosive Atmosphere Detection	11	6	11	15	2	3	24
All Injuries vs. General Accident Prevention	57	95	57	8	13	23	126
TOTAL	294	427	294	128	63	95	650

The comparison of the theoretical random values to actual values indicates that injuries lead predominately for haulage, roof and rib fall, handling materials, machinery, electrical, lift/pull & slip/fall, and all injuries versus general accident prevention. Training led only for explosions/ignitions. The significance of these leads is determined from the chi-square test which will indicate if the variances are within a confidence level for non-random hypothesis. The equation is:

$$x^2 = \sum_{j=1}^{k} \frac{(f_j - F_j)^2}{F_j}$$

where: f_j is the observed frequency,
F_j is the theoretical frequency, and
k is 3 because there are three factors:
Training Leads, Injuries Lead, and In Phase

A sample calculation for haulage is

$$x^2 = \left[\frac{(46 - 24)^2}{24} + \frac{(6 - 24)^2}{24} + \frac{(1 - 5)^2}{5} \right]$$

$$= 20.2 + 13.5 + 3.2 = 36.9$$

which is highly significant for k - 1, or 2 degrees of freedom.

In general it is statistically significant that training was given in the same quarter or after some injuries occurred in the time period from January 1972 to July 1974. Test results are in Table 21.

Let us turn to the question of the effectiveness of training. Can we show causally through the time series data that certain types of training are effective? Is it more effective when given after the injuries, before or in the same quarter?

The random chance of two successive decreases in injury rate for a quarter of training is P = 1/2 · 1/2 or 1/4 . It is assumed that the chance of the rate staying the same (other than zero) is negligible. When two zeroes occur successively after a finite injury rate, the training quarter is assumed effective. One out of four training units is effective on a random basis. If training is given during a period of no injuries, then it is considered as independent but included in the total of possible chances.

TABLE 21

STATISTICAL SIGNIFICANCE OF INJURIES OR TRAINING OCCURRING FIRST IN THE TIME SERIES

Injuries vs. Training	Injury Lead	Training Lead	In Phase
Haulage vs. Haulage A/P	> 0.005	-	-
Roof and Rib vs. Ground Control	> 0.005	-	> 0.005
Handling Materials vs. General Accident Prevention	> 0.005	-	> 0.005
Machinery vs. Machinery A/P	> 0.005	-	-
Electrical vs. Electrical Qual/Requal	> 0.005	-	-
Lift/Pull & Slip/Fall vs. General Accident Prevention	> 0.005	-	> 0.005
Explosions/Ignitions vs. Explosive Safety and Explosive Atmosphere Detection		> 0.1	-
All Injuries vs. General Accident Prevention	> 0.005	-	> 0.005

Haulage accident prevention training has been effective in a statistically significant sense as shown in Table 22. Since these are comparisons of injury and training time series with no more than one quarter lag, a cause of the reduced haulage injury rate is the training. Furthermore, this causal relationship occurred for time series in which haulage accidents occurred previous to the introduction of training. Training given first or in the same quarter as injuries initially appeared to be random. Haulage training given in response to haulage injuries causally reduces the haulage injury rate.

TABLE 22

EFFECTIVENESS SIGNIFICANCE OF HAULAGE A/P TRAINING

Number of Mines	Training Quarters	Effective Actual	Effective Random	Unclear or Independent	Ineffective	χ^2 Statistical Significance
46 Injury Leads	82	34	21	28	20	
6 Training Leads	17	4	4	7	7	Random
1 In Phase	2	1	0 or 1	1	0	Random
Total	101	39	35	36	26	<0.001

TABLE 23

EFFECTIVENESS SIGNIFICANCE OF GROUND CONTROL TRAINING

Number of Mines	Training Quarters	Effective Random	Effective Actual	Unclear or Independent	Ineffective	χ^2 Statistical Significance
57 Injury Leads	99	25	32	35	32	Random
73 Injury Leads	229	56	72	83	74	<0.05 Non-Random
38 Training Leads	135	34	34	59	42	Random
20 In Phase	95	24	32	19	44	Random/ almost 0.1
Total	459	115	138	16	16	>0.05

Rib and roof control is significant to 95 percent according to the results in Table 23. This is not as strong as haulage training. The significance exists only when the training is introduced after injuries occurred initially.

TABLE 24

EFFECTIVENESS SIGNIFICANCE OF GENERAL ACCIDENT PREVENTION TRAINING ON HANDLING MATERIALS INJURIES

Number of Mines	Training Quarters	Effective Random	Effective Actual	Unclear or Independent	Ineffective	χ^2 Statistical Significance
57 Injury Leads	99	25	32	35	32	Random
25 Training Leads	72	18	9	41	22	Random
20 In Phase	94	24	33	22	39	0.1
Total	265	66	75	98	92	Random

Table 24 indicates that the effect of general accident prevention courses upon handling materials injuries is not statistically significant. The χ^2 is 1.0 for the total of 265 quarters of training.

TABLE 25

EFFECTIVENESS SIGNIFICANCE OF MACHINERY ACCIDENT PREVENTION/QUALIFICATION TRAINING

Number of Mines	Training Quarters	Effective Random	Effective Actual	Unclear or Independent	Ineffective	χ^2 Statistical Significance
21 Injury Leads	-	7	10	9	11	Random
1 Training Lead	-	-	-	1	-	-
0 In Phase	-	-	-	-	-	-
Total	29	7	8	10	11	Random

Machinery accident prevention/qualification training courses are not prevelent enough to have any effect with the small sample size shown in Table 25. A shift of three training quarters from ineffectiveness to effectiveness (an increase of 30 percent) would make the training causally significant. However, we should consider that the training does not reduce injuries with statistical significance.

TABLE 26

EFFECTIVENESS SIGNIFICANCE OF ELECTRICAL QUALIFICATION/REQUALIFICATION TRAINING

Number of Mines	Training Quarters	Effective Random	Effective Actual	Unclear or Independent	Ineffective	χ^2 Statistical Significance
53 Injury Leads	147	37	35	84	28	Random
14 Training Leads	53	14	10	26	17	Random
10 In Phase	37	9	15	17	5	<0.05
Total	237	59	60	127	50	Random

In the case of electrical qualification/requalification training in Table 26, the training seems to be effective when it is conducted initially in phase with injuries. The reason is that the amount of injuries is small and the training can fall in quarters without injuries within two quarters. Training under such a condition is considered independent neither effective nor ineffective. Almost one half were independent. Thus, in phase training it appears to be effective to a 95 percent confidence.

General accident prevention training courses, as related to slip/fall and lift/pull injuries in Table 27, causally reduce injuries to a significance of 95 percent for the total of 308 quarters of training. When injuries occurred first in the ten quarter time period, the significance increased to 99 percent confidence. When training leads initially or is in phase with injuries, the relationship is random.

TABLE 27

EFFECTIVENESS SIGNIFICANCE OF GENERAL ACCIDENT PREVENTION TRAINING ON LIFT/PULL AND SLIP/FALL INJURIES

Number of Mines	Training Quarters	Effective Random	Effective Actual	Unclear or Independent	Ineffective	χ^2 Statistical Significance
75 Injury Leads	186	47	65	55	66	>0.01 Non-Random
21 Training Leads	55	14	10	23	22	Random
18 In Phase	67	17	19	20	28	Random
Total	308	77	9	98	116	0.1, but almost >0.05

TABLE 28

EFFECTIVENESS SIGNIFICANCE OF EXPLOSIVES SAFETY AND EXPLOSIVE ATMOSPHERE DETECTION TRAINING

Number of Mines	Training Quarters	Effective Random	Effective Actual	Unclear or Independent	Ineffective	χ^2 Statistical Significance
6 Injury Leads	19	5	3	16	0	Random
15 Training Leads	72	18	21	33	18	Random
3 In Phase	12	3	2	9	1	Random
Total	103	26	26	58	9	Random

In terms of the ten quarter time series in Table 28, the explosion safety and explosive atmosphere detection training appears to have no effect upon the level of injuries for the mines having injuries. The reason is that the training is so extensive in various methane detection courses within and previous to the 1972 through mid-1974 time period that the injuries are few. The amount of training in for mines not having injuries is extensive. Thus, we have here an instance in which sample is not large enough to measure the full impact of training. Examiniation of the increase in training rate and injury rate over the years for this type of injury clearly indicates that the extensive training has had an impact.

Repetition of Training

The relationship of the haulage accident prevention training and haulage type injuries over time was examined to determine how frequently training should be conducted. The scheme is to determine in which quarter the injury rate exceeds the injury rate of the quarter in which the training was given. Table 29 is a tabulation of the frequency distribution over the number of quarters. It is assumed that training is repeated in the quarter in which the injury rate exceeds the initial rate. Every quarter, every other quarter and every third quarter are the most frequent requirements. This is likely to vary with type of training.

TABLE 29

DURATION OF TRAINING EFFECTIVENESS

(Number of Quarters until Injury Rate Exceeds Injury Rate in Quarter Training was Given)

Number of Quarters	1	2	3	4	5	6	7	8
Frequency	22	15	11	7	9	2	3	1

If the haulage training is given annually, twenty two (4, 5, 6, 7, 8), of the seventy cases (1, 2, 3, 4, 5, 6, 7, 8) would be improved in safety because the requirement for twenty six cases (1, 2, 3) is not met. Semi-annual training would improve safety for forty eight of the cases (2, 3, 4, 5, 6, 7, 8), which is an improvement of greater than 100 percent over the annual training.

Another piece of information can be drawn from Table 29. In 22 cases the injury rate increased in the following month after training and in 48 (22 + 15 + 11 + 7 + 9 + 2 + 3 + 1) cases it decreased. This is a total of 70 cases (independent and unclear ratings are removed), which if random would be 35 increase and 35 decrease. The 48 decreases versus 22 increases is non-random statistically significant to greater than 99 percent confidence level. The result is as expected since the stricter condition of two successive decreases is statistically significant.

Further Study Needs

Certain areas of training and injuries are worth additional study with time series data. These are:

- Verify which typs of training causally reduce various types of injuries. This would include verification by obtaining a random distribution for mines with injuries in which no training was given. Compare improvement in injury rate of each category of training to that obtained from general accident prevention training for that category of injury. This would determine in detail if general accident prevention is sufficient training for most types of injuries.

- Extend the data set through the first two quarters of 1975 and perform an analysis similar to that performed on the data extending through the first two quarters of 1974.

- Use the available monthly data to verify any questionable quarterly comparison in training and injuries.

- Complete the mathematical model and develop a computer program for up dating the level of effectiveness of the training of each category upon its matching injury rate down by hand for this report.

PHASE IV ANALYSIS

SUMMARY

Introduction and Purpose

As noted in the introduction to the report of analysis for Phase II of this project there are numerous indications in the actions of governments, mine management, and organized labor that there is widespread belief that training has a key role in the reduction of mine injury rates. Mandatory minimum training in specified topics is required by the 1969 Coal Mine Health and Safety Law. States require certification of working in certain mining occupations and offer training programs to prepare miners for the certification testing. Some states also require minimum mining experience before certain mining tasks that involve work near machinery or as machine operators as well as the experience required for certification. Mine operators have made greater and greater investment in training programs, training facilities, and instructional staffs. The latest UMWA-BCOA contract calls for training of new miners and miners assigned to new tasks.

Wide variation in the approaches to meeting the requirements for training were found in the survey task. This variation includes many factors including the definition of objectives, who is trained, where and when the training is conducted, the instructors and training methods, use of training aids and simulations, and the context in which the "safety" portions of the training is carried out. It is obvious that the costs of these different approaches to training will also vary. The purpose of this phase of the project is to add an evaluation of economic effectiveness to the approaches to training that were found to be effective in the sense of their contribution to reduced injury rates. The specific task requirements included the determination of an economic trade off between money currently being spent in the areas of training disclosed by the survey and the estimated reduction of accidents and health protection of mines. Recommendations were to be made on the basis of relationships among the degree and type of training in a particular area, and the time of and total cost of such training conducted with the various mining assignments.

Problems and Reduced Objective

Two problems stemming partly from the nature of the training being conducted and the available data and partly from some decisions for use of that data in the research design made the evaluation of economic effectiveness as outlined in the statement of work an objective beyond the reach and scope of this project. The data analysis revealed that just as there are

variations of training objectives, training methods, training effort, etc., there are also variations in the effectiveness of that training with respect to change to injury rates. The fundamental problem is that there is no apparent relationship between the factors that describe training and its effectiveness. Mines (or specific training programs) were found to be normally distributed along the range of effectiveness ratings for both overall and specific categories of training course objective. Analysis of each MESA course separately instead of aggregated according to objective categories plus analysis of data for training not reported in the MESA training data system along with data descriptive of the other parameters for who is trained and when, where, how, and by whom the program is conducted would have improved the research design. However, this would not have changed the fact that these factors are less important to the effectiveness of the training than the way the trainees perceive the relevance of the training and management's commitment to their safety and health.

The other hindrance to evaluation of economic effectiveness is the fact that training costs are not well documented or even appreciated. Cost per hour of instruction depend on many factors that vary with time, location, and training course. The class size, production time used, whether or not it is really production time, sharing of the cost by the trainee, the company, MESA, HEW, state agencies, and even local government, and the nature of the topic as well as choice of method and media all contribute to making accurate estimates of costs a matter beyond the capability of the data available for this analysis. However, there is one trade off potential that can be examined and presented in terms that will have some meaning for the mining industry. This is the relationship between lost days per thousand tons of production and employee-course hours per thousand tons of production. Both measures represent a "cost" per unit of production. Although any effort to convert lost days and course hours into dollar costs is not practical for the scope of training included in this summary, these basic measures tell something useful about the trade-off potentials for "effective" training.

Findings

Total lost days versus total training plus seven injury types versus course categories were examined in a search for an example of the trade-off between training hours and lost days. Ground control training to reduce lost days due to roof and rib fall injuries was found to give the most reliable and reasonable curve to illustrate the relationship. Figure 25 shows that mines having relatively high lost day rates due to fall of roof or rib can expect subsequent rates to drop sharply with slight increases

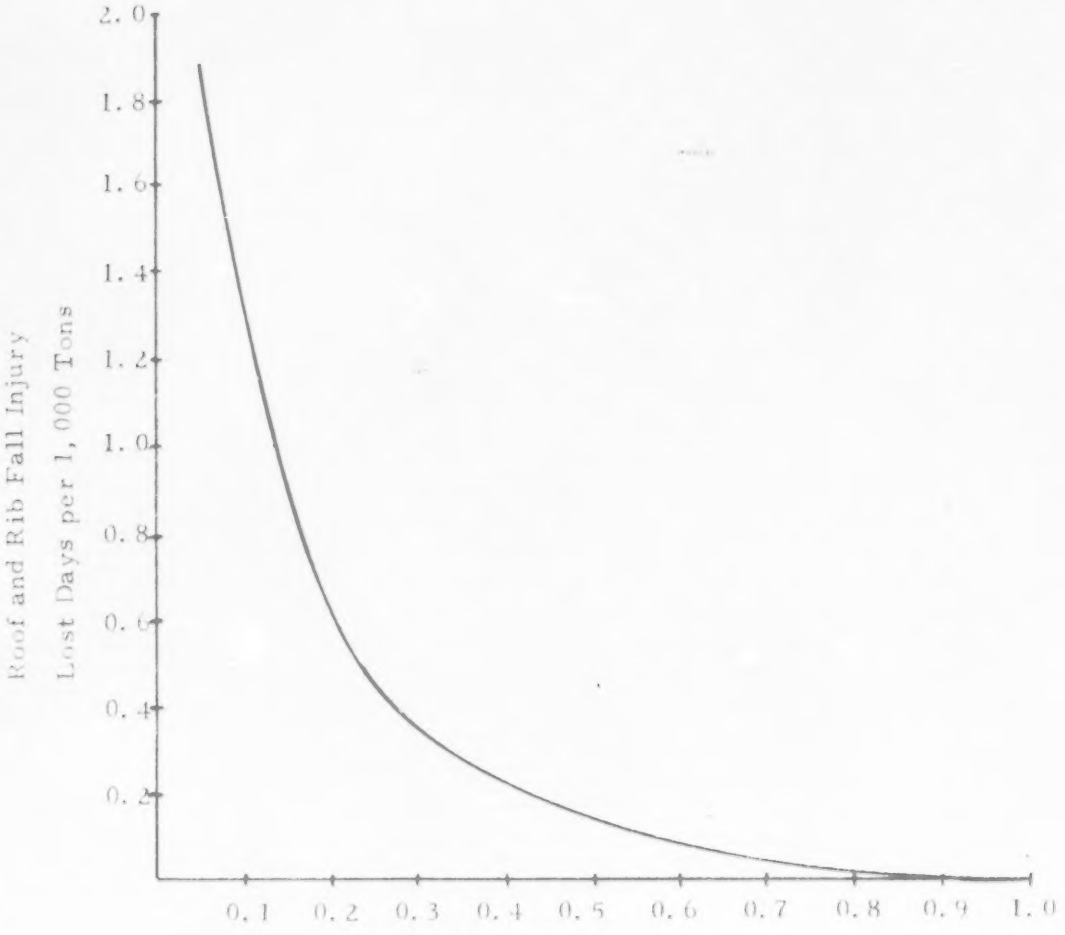

Figure 25

Expected Trade-Off Between Lost Days and Effective Course Hours

in the rate of effective training. Mines whose rate of training is already relatively high with low lost day rates should not expect much reduction to lost day rates to result from higher rates of training. Since this curve is only an estimate of what the average expectations are for reduced lost days following increased training its use is limited. Note that it is based

on cases of increased training that were effective because the subsequent lost day rate was reduced. Reductions in the rate of training do not necessarily bring on expected increases to lost day rates. Training one miner for one hour for every thousand tons of production will not ensure zero lost days either. The data does show, however, that no mine having effective training at a rate greater than 0.4 hours per thousand tons had a lost day rate greater than 0.3 days per thousand tons. It is also true that many other mines recorded equally low lost day rates with relatively low reported training rates. In fact, there were nine mines that reported no ground control training in the 1972 to mid-1974 period whose average lost day rate for the same period was 1.523 per thousand tons. The range in this rate for these nine mines extended from a low of 0.020 to the highest in the data at 92.42 days per thousand tons. This variation of experience is indicative of the fact that just as the levels of training and its effectiveness vary widely, so do the efforts going into roof support, cabs and canopies, and inspection. Mines that tend to be above average in training effort and affectiveness will also be carrying out the other activities that should improve their safety records.

Having acknowledged that more than just training is involved in the reduction of lost day rates, the average mine that did not report any ground control training, but did have roof and rib fall inquries will be used to illustrate the cost trade-off between lost days and effective training hours. Assume that the administrative and overhead costs of the average day of lost time equal those of putting on a two hour roof and rib control course for four men. Time taken from production is also equal and the total expected cost per unit of production for injuries and training is simply the sum of lost days and course hours. For every 10,000 tons the average mine in this example incurred a total cost of 15 days or $750 worth of nonproductive labor at $50 per day. If instead of zero training, the average mine had conducted just four hours of effective ground control training the expected lost days would be reduced to two. The total cost comes to only $125 worth of nonproductive labor or a saving of over 80 percent realized by moving from zero to approximately the industry average rate of training.

There are many unproved assumptions in this very simple example, but it does illustrate results that can be expected on the basis of what was happening in a representative sample of the industry over a two and a half year period. If such savings are possible, why doesn't training receive the emphasis and attention from management that seems to make it pay off? The answer may be found in relating this example to the total production costs. Although this sort of data is not commonly available information from various planning and economic analysis studies does allow some reasonable estimates. At the same time the average company was incurring

a cost of $750 for the lost days due to roof and rib fall injuries for every 10,000 tons of production in this example, another $230 was incurred for lost days due to other types of injuries. Productivity was 11.19 tons per man-shift so at $50 per day every 10,000 tons will cost another $44,680 in wages. Capital other operating expenses spread over a 20 years mine life can be estimated at another $50,000 (probably 5 to 15 percent low) for every 10,000 tons of production. So it can be very easily seen that the costs of injuries form a very insignificant part of the mining operation and the training is even less. Safety may have a pay-off, but the relative value of these returns are apparently too small to be taken seriously.

If the direct costs of injuries and benefits of training are so small relative to the overall costs, how do the costs of assessments due to violation of safety standards compare? On the basis of 98 mines in the data set for which some information on assessments was available the average assessment per 10,000 tons of production was only $510, or the same order of magnitude as the costs of injuries and training. Since only about $65 worth of that $510 in assessments is eventually paid, it is also easy to see that mine operators are not being strongly pressured toward safer operations by this aspect of enforcement. As a matter of fact the proportion of assessments that is successfully contested and delayed amounts to some $44,500 for the typical million ton per year operation - about right for the lawyer who can contest the penalties or interpretation of standards and even "prove" that the estimates in this discussion of costs are not applicable to any particular mine.

Strong economic incentives from mine operators to improve safety do not exist in the costs of injuries or civil penalties unless the inspector closes a mine. The only substantial economic benefits of better trained, more skilled (and safer) miners appears to be the potential for increased productivity that might result. Figure 26 shows a plot of injuries per million man hours versus tons per man shift for 36 companies and divisions of underground mines for the 1972 to mid-1974 period. This plot does not indicate that safety is necessarily obtained at the cost of reduced productivity. This is not the same as saying that various activities intended to improve safety since the passage of the 1969 Coal Mine Health and Safety have not contributed to the decline in productivity. Only one of the cases where productivity is greater than ten tons per man shift is in the cluster of eight cases that had a very high average injury rate (cluster median is about 100 inj./MMH). Other than the eight cases in that cluster these plots indicate only that injury rates and productivity are independent. That cluster of eight cases also indicates that high productivity is more likely to be found in a safe mine than is low productivity.

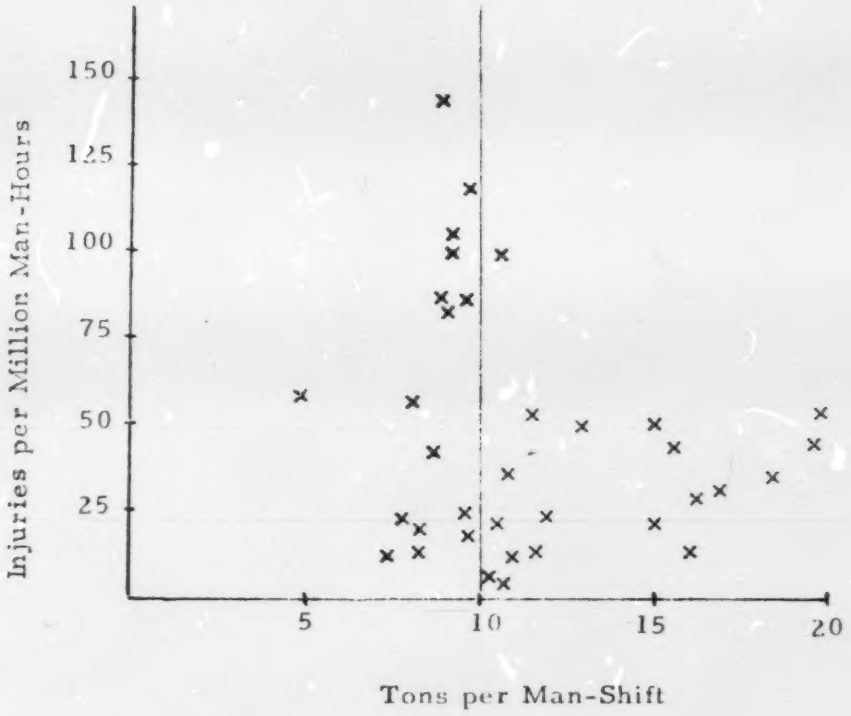

Figure 26

Productivity versus Injury Rate

The message of this economic evaluation is that safety training should not be isolated from the primary need for training in production, maintenance, and supervisory skills. The economic incentives for a work force that can safely produce 15 tons per man shift instead of 10 tons per man shift with above average injury rates are far greater than the economic incentives for just reducing injury rates while productivity stays constant. If safety pays, it must be sold to the industry on the basis of safer workers being more productive workers. If this proposition can not be made valid by government, labor, and management cooperation, significant improvement in the safety of mining should not be expected.

DATA ANALYSIS

Trade-Off Curve Development

Analysis of time series data established that there is a causal relationship between training and injury rates. This economic evaluation of training is based on finding a curve or set of curves that show the expected (average) injury rate subsequent to various training rates. The search for such a curve centered on annual data for companies or divisions having effective training programs. In this instance "effective" is simply defined as a reduction to injury rates between 1973 and 1974 after the training rate was increased between 1972 and 1973.

Table 30 presents average data for four groups of cases of increased total training between 1972 and 1973. Of 43 companies or divisions in this data, 33 had a higher rate of training in 1973 than in 1972. The 26 cases of "effective" training were grouped according to the range of 1973 lost day rates. It could be expected that a high rate will show more improvement from a given rate of training than is possible if the company already has a relatively low lost day rate. The plot of lost days versus employee courses in Figure 27 shows that this was true, but it also shows that the group having greater than five lost days per 1000 tons in 1973 was also training at the highest rate of all four groups in 1973. This indicates that the high 1973 training rate probably resulted from the high 1973 lost day rate. The time series analysis also indicated that training tends to be carried out in response to injury experience. All three "effective" groups had approximately the same increase to their training rates and the improvement of lost day rates was proportioned to the room for improvement. However, the fact that the highest rates of training correspond to the greatest improvement could be misleading. A specific injury type versus the category of training that should reduce that injury type may provide a better basis for a trade-off curve.

Table 31 presents seven sets of average data for specific injury types versus training category. The progression in the table and plots in Figures 28 through 34 is from the least to most suitable for estimating a trade-off curve. Lift/pull and slip/fall injury plots in Figure 28 shows the same pattern of a high injury rate leading to the highest training rates as with lost day rate in plots of Figure 27. The two groups of cases starting from the high and mid range levels of handling materials injury rate in 1973 show the expected change in slope with change in injury and training rates in Figure 29. However, those eight cases having both

TABLE 30

TOTAL LOST DAYS PER 1,000 TONS
VERSUS TOTAL EMPLOYEE-COURSES PER 1,000 TONS

	No. of Cases	Lost Day Rate 1973	Lost Day Rate 1974	Training Rate 1972	Training Rate 1973
$TR_{73} > TR_{72}$	35				
$LDR_{74} < LDR_{73}$	26				
$LDR_{73} \geq 5.0$	6	11.55	1.29	1.00	1.73
$5.0 > LDR_{73} \geq 2.0$	9	3.05	1.00	0.53	1.23
$2.0 > LDR_{73}$	11	0.70	0.34	0.54	1.21
$LDR_{74} > LDR_{73}$	7	2.02	6.13	0.73	1.68

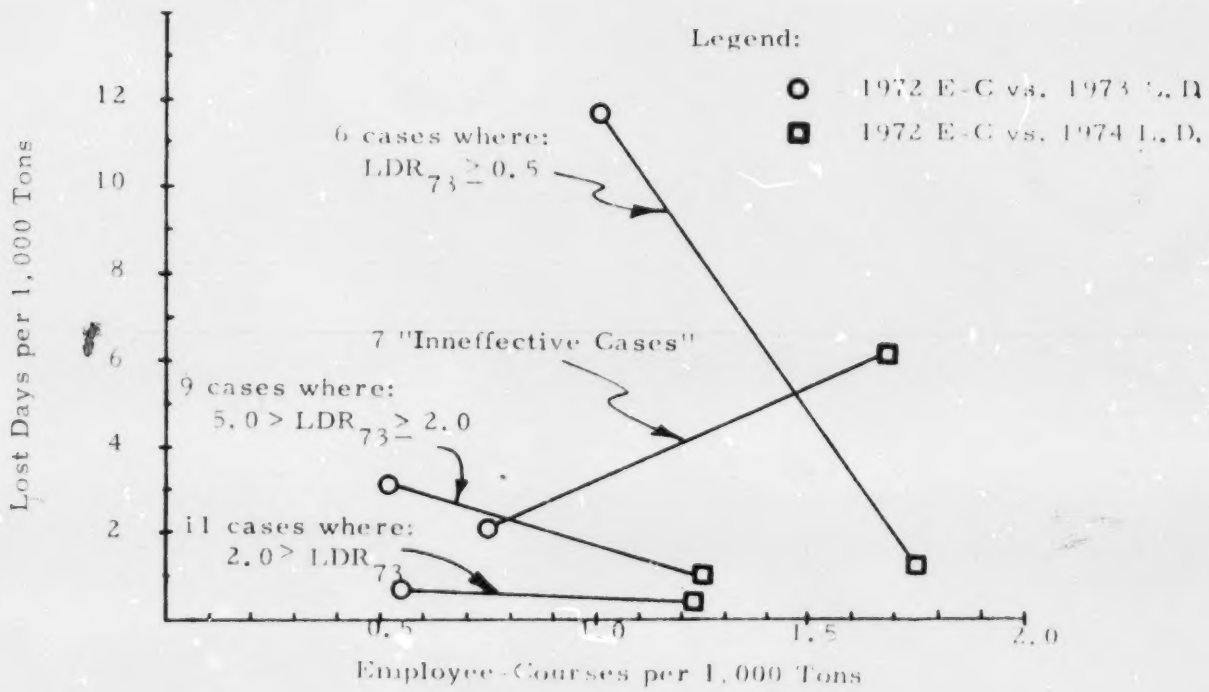

Figure 27

Total Lost Days per 1,000 Tons Versus
Total Employee-Courses per 1,000 Tons

TABLE 31

SPECIFIC INJURY TYPES VERSUS
TRAINING CATEGORY

A. Lift/Pull and Slip/Fall Injuries vs. General Accident Prevention:
(19 cases where $TR_{73} > TR_{72}$)

Co/Div Group	No. of Cases	Injury Rate 1973	Injury Rate 1974	Training Rate 1972	Training Rate 1973
$IR_{73} \geq 20.0$	4	34.67	18.59	70.33	93.87
$20.0 > IR_{73} \geq 5.0$	4	9.93	9.41	14.04	28.68
$5.0 > IR_{73}$	6	3.17	2.16	66.29	78.76
All Effective	14	14.10	8.36	52.51	68.77
$IR_{74} > IR_{73}$	5	13.84	19.82	15.75	29.23

B. Handling Materials Injuries vs. General Accident Prevention:
(19 cases where $TR_{73} > TR_{72}$)

Co/Div Group	No. of Cases	Injury Rate 1973	Injury Rate 1974	Training Rate 1972	Training Rate 1973
$IR_{73} \geq 15.0$	4	20.87	13.13	26.19	42.07
$15.0 > IR_{73} \geq 5.0$	4	11.32	5.40	75.67	102.16
$5.0 > IR_{73}$	8	2.65	1.18	0.40	6.96
$IR_{74} > IR_{73}$	3	5.68	7.15	133.47	158.77

C. Electrical Injuries vs. Electrical Qualification/Requalification:
(32 cases where $TR_{73} > TR_{72}$)

Co/Div Group	No. of Cases	Injury Rate 1973	Injury Rate 1974	Training Rate 1972	Training Rate 1973
$IR_{73} \geq 2.0$	8	3.70	1.06	2.58	112.42
$2.0 > IR_{73} \geq 1.0$	7	1.49	0.35	8.35	47.92
$1.0 > IR_{73}$	11	0.28	0.00	3.36	98.73
$IR_{74} > IR_{73}$	6	1.07	1.75	5.92	80.22

TABLE 31 (Cont.)

D. Explosion/Ignition Injuries vs. Explosive Atmosphere Detection:
(28 cases where $TR_{73} > TR_{72}$)

Co/Div Group	No. of Cases	Injury Rate 1973	Injury Rate 1974	Training Rate 1972	Training Rate 1973
$IR_{73} > 0.0$	2	0.97	0.30	188.5	364.0
$IR_{73} = IR_{74} = 0.0$	24	0.00	0.00	287.5	642.4
$IR_{74} > IR_{73}$	2	0.14	0.91	280.5	483.8

(12 cases where $TR_{73} < TR_{72}$)

$IR_{73} > 0.00$	2	1.35	0.00	156.5	121.7
$IR_{73} = IR_{74} = 0.0$	9	0.00	0.00	540.2	340.5
$IR_{74} > IR_{73}$	2	0.00	4.91	495.0	217.1

(2 reported neither injuries nor training)

E. Haulage Injuries vs. Haulage Accident Prevention:
(9 cases where $TR_{73} > TR_{72}$)

Co/Div Group	No. of Cases	Injury Rate 1973	Injury Rate 1974	Training Rate 1972	Training Rate 1973
$IR_{72} \geq 8.0$	3	7.58	5.30	3.89	19.08
$IR_{72} < 8.0$	3	12.41	7.83	0.96	59.58
$IR_{74} > IR_{73}$	3	3.40	5.55	1.45	12.74

F. Machinery/Hand Tool Injuries vs. Machinery Qualification:
(4 cases where $TR_{73} > TR_{72}$)

Co/Div I.D.	1972	1973	1974	1972	1973	1974
042	2.02	2.56	1.67	0.00	0.28	0.00
197	5.79	5.50	1.94	4.63	20.08	7.26
239	1.90	8.62	5.48	0.00	1.72	0.000
308	11.83	6.05	4.29	0.00	0.73	5.58

TABLE 31 (Cont.)

G. Roof and Rib Fall Injuries vs. Ground Control:
(25 cases where $TR_{73} > TR_{72}$)

Co/Div Group	No. of Cases	Injury Rate 1973	Injury Rate 1974	Training Rate 1972	Training Rate 1973
$IR_{74} < IR_{73}$	17	7.58	3.12	62.38	226.38
$IR_{73} \geq 8.0$	7	13.36	5.94	38.50	164.78
$IR_{73} < 8.0$	10	3.54	1.15	76.71	263.35
$IR_{74} > IR_{73}$	8	5.79	7.62	186.17	200.00
(Extreme cases where $TR_{73} > TR_{72}$)					
Highest IR_{73} (Div 261)		20.13	3.29	36.36	82.19
Highest TR_{72} (Div 141)		3.53	0.00	45.77	633.86
(Mines where $TR_{73} > TR_{72}$)					
$IR_{72} \geq 10.0$	19	11.60	3.14	71.35	282.05
$10.0 > IR_{72} \geq 5.0$	19	6.90	2.32	34.78	244.09
$5.0 > IR_{72}$	24	4.10	1.36	33.62	271.68
$IR_{74} > IR_{73}$	17	6.76	14.92	23.78	136.07

injuries and training at a low rate do not fit the pattern. Electrical injury experience relative to electrical qualification training shows a rather different situation in Figure 30. The high and mid range injury rate groups have virtually identical slopes, but apparently the high injury rate also lead to higher than average training rates. Explosion/ignition injuries were so few that no hint of a curve can be found in Figure 31.

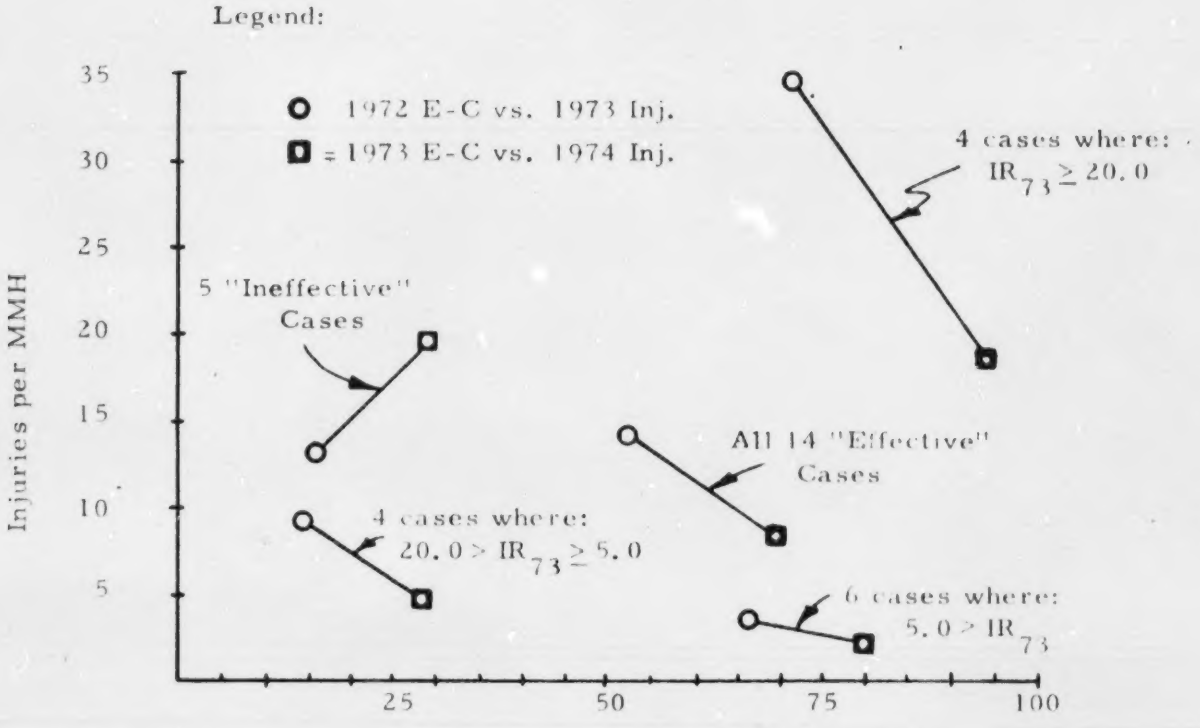

Figure 28

Lift/Pull and Slip/Fall Injuries per MMH Versus
General Accident Prevention Employee-Courses per MMH

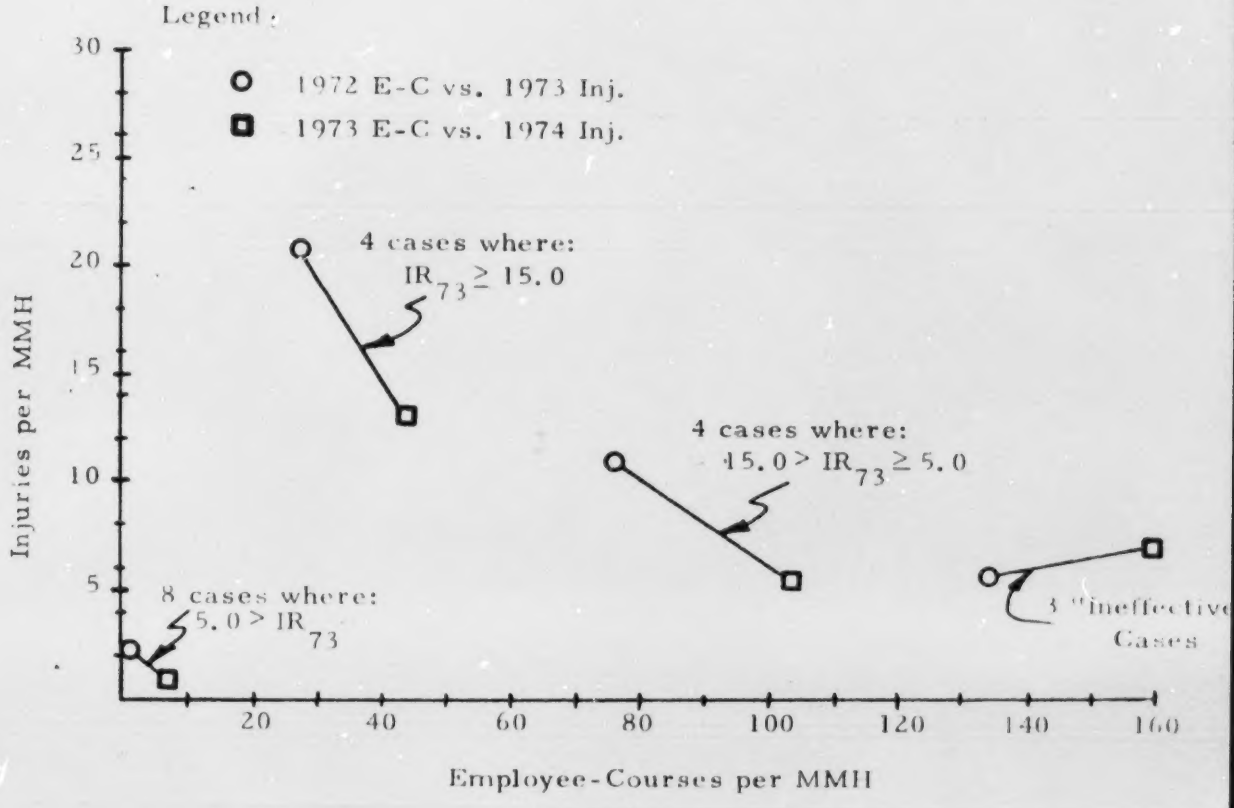

Figure 29

Handling Materials Injuries per MMH Versus
General Accident Prevention Employee-Courses per MMH

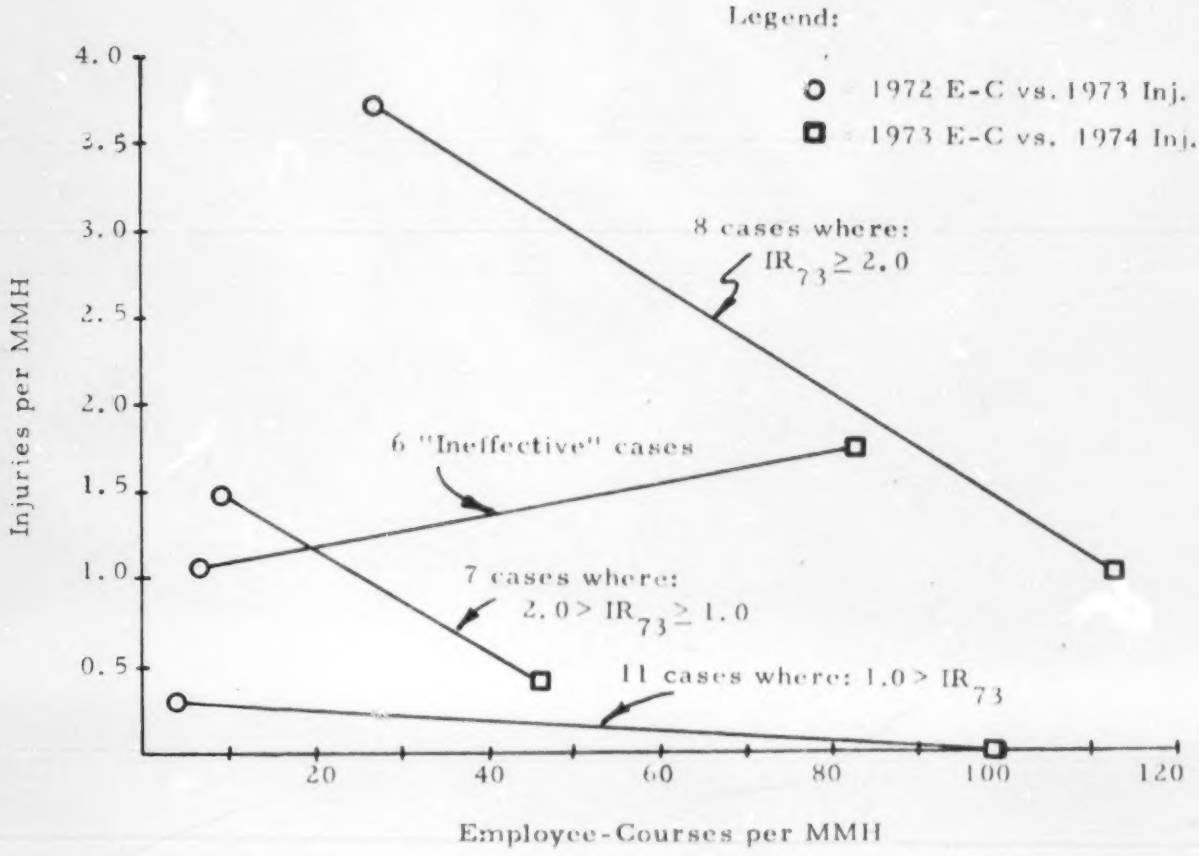

Figure 30

Electrical Injuries per MMH Versus
Electrical Qualification/Requalification Employee-Courses per MMH

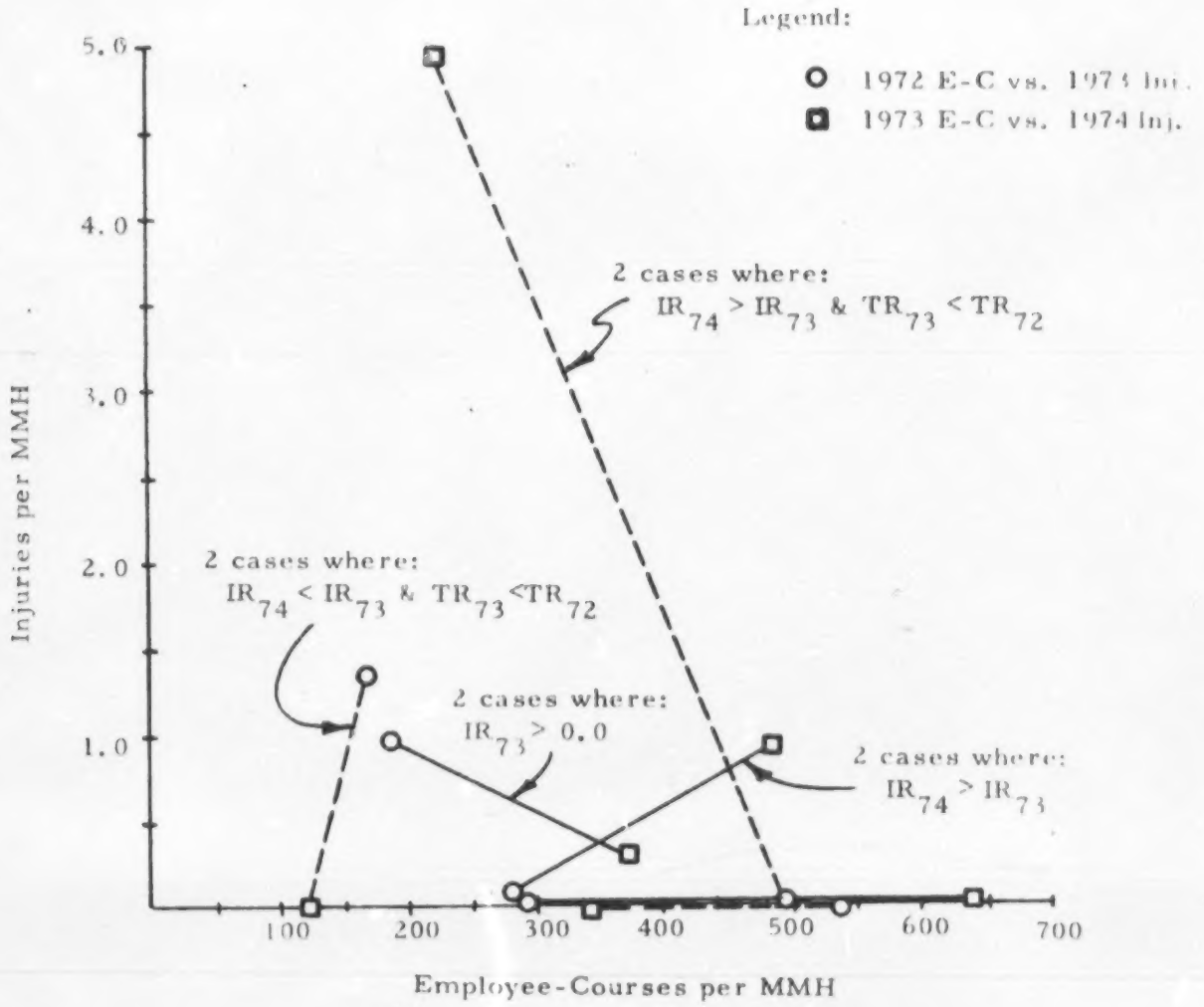

Figure 31

Explosion/Ignition Injuries per MMH
Versus Explosive Atmosphere Detection Employee-Courses per MMH

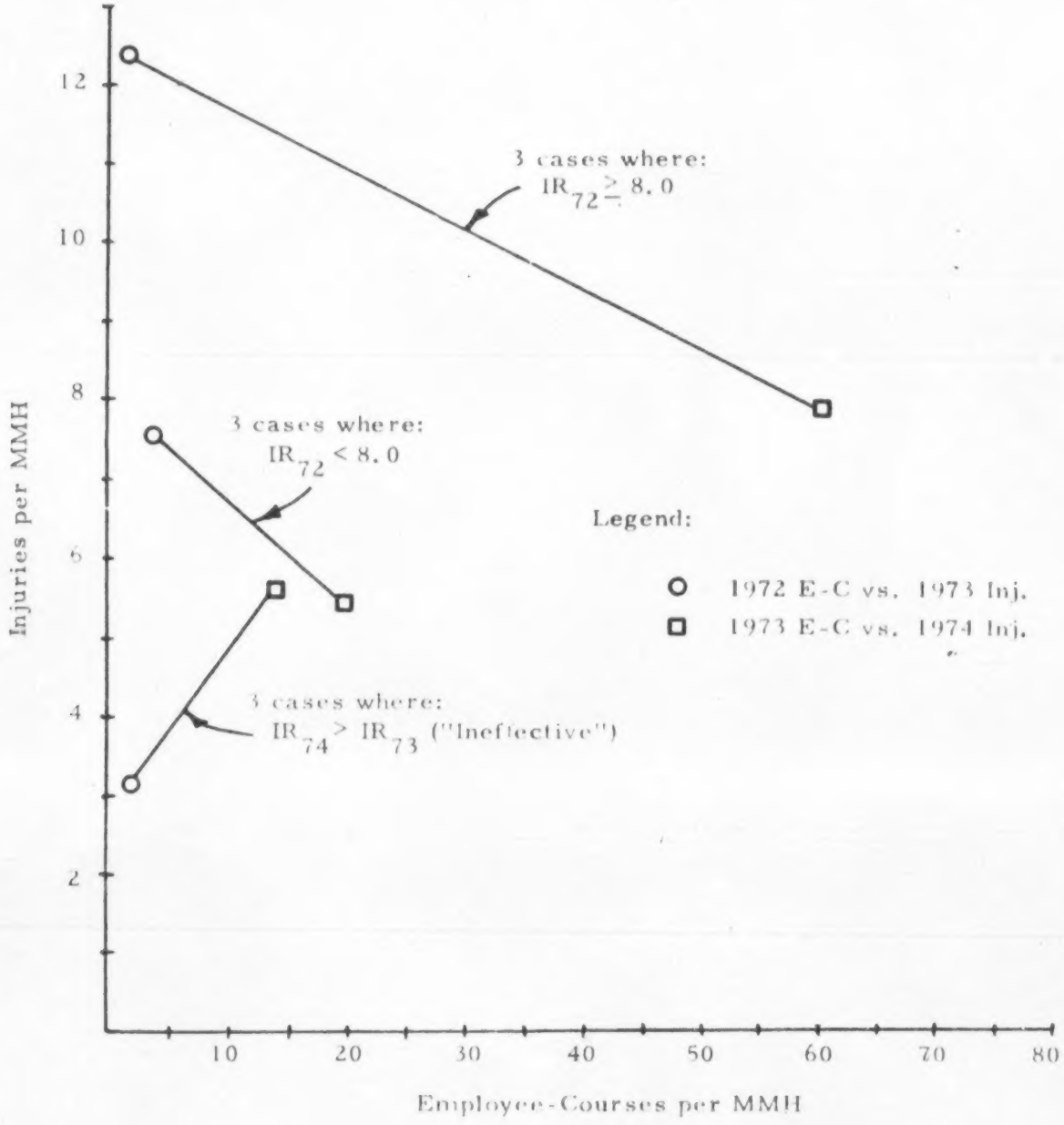

Figure 32

Haulage Injuries per MMH Versus
Haulage Accident Prevention Employee-Courses per MMH

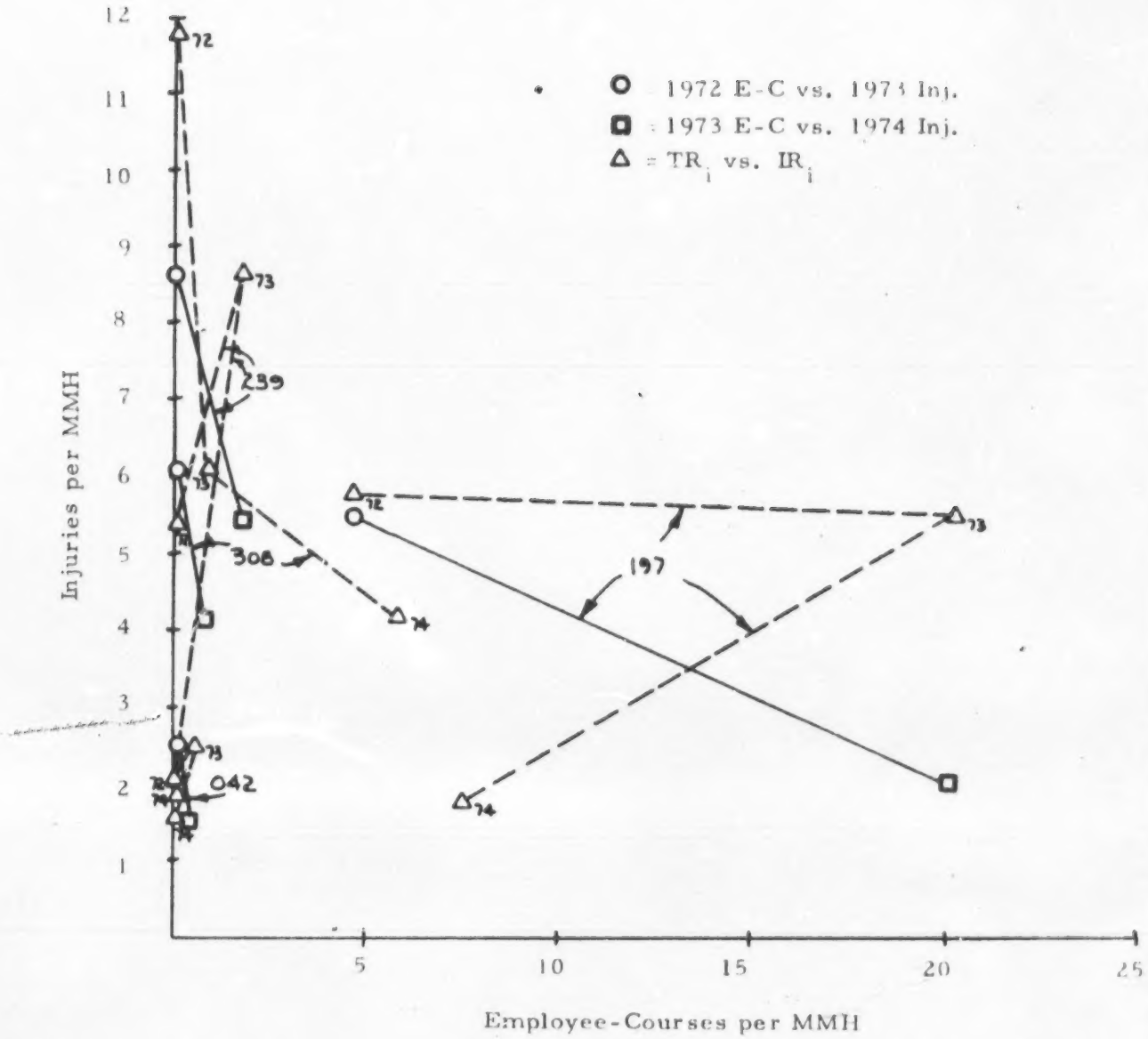

Figure 33

Machinery/Hand Tool Injuries per MMH

Versus Machinery A/P or Qualification Employee-Courses per MMH

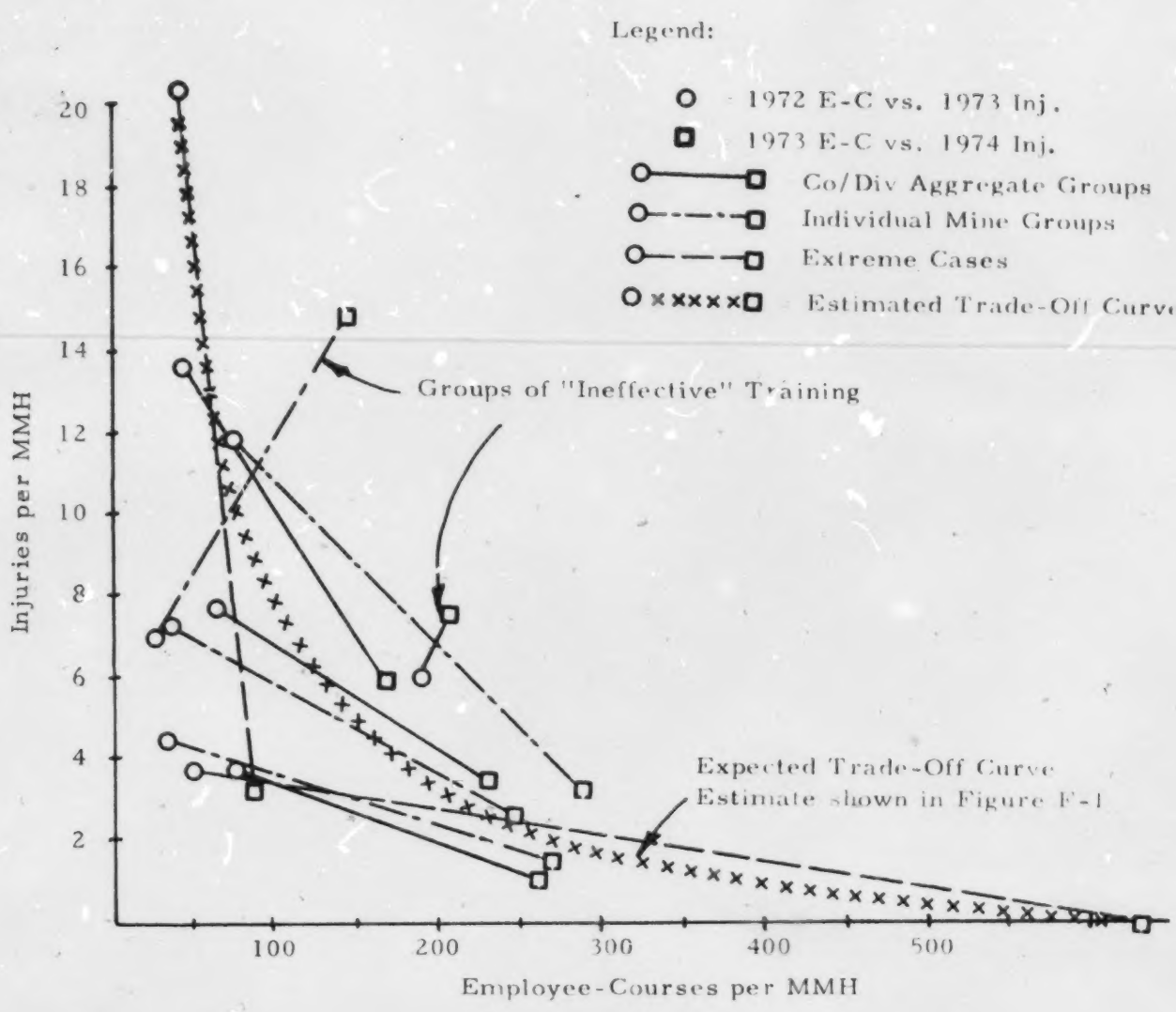

Figure 34

Roof and Rib Fall Injuries per MMH
Versus Ground Control Employee-Courses per MMH

It is noteworthy that the two "high" increases to this rate were for companies that had decreased the training. This is interesting, but not any real proof that decreasing training levels leads to increased injuries. The percent of all zero injury rates and improved injury rates is about the same for both increased and decreased training rates. The plots in Figures 32 and 33 both indicate that in the new cases where haulage or machinery training was reported, its level was a function of that type of injury in the year the training was given. Mine company number 308 shows a logical progression of increased training rate and decreased injuries in the unlagged plots in Figure 33.

Finally, Figure 34 shows the origins of the curve reported as the best example of the trade-off in Figure 25. When both groups and extreme value examples appeared to suggest the continuous curve, data for individual mines was also plotted. The plot of the curve in Figure 25 was estimated and the scales converted to hours of training and lost days per thousand tons on the basis of course duration, average productivity, and average lost days per injury.

Cost Analysis

A study of training costs in a cross section of U.S. industry conducted by the U.S. Navy provides some valuable insight into the nature of training costs.[19] The cost of various "systems" approaches to training and convention classroom lecture-recitation approaches were found to be $10.00 and $9.75 per trainee hour, respectively. However, the time to achieve a course objective was also found to be 70 percent of conventional approaches when a system approach is used. This turns into a large potential cost savings because the students' pay forms the largest single element of total training cost. This proportion averaged at 72.6 percent of total cost and ranged from 59.1 percent for utility company technicians to 85.5 percent for management training. Large variation is also found in cost per trainee hour ranging from $3.50 for basic technology in industry to over $100 for pilot training for airlines.

[19] Training Analysis and Evaluation Group, Naval Training Equipment Center, Orlando, Florida, reported in Naval Education and Training: A Symposium, January 10-11, 1974, part V, published by the National Security Industrial Association, Washington, D.C.

Since the student cost represents such a large portion of training cost in these examples and the training of miners is very likely to follow the same pattern, the search for a trade-off between time lost due to injuries and time devoted to training appears to be a sound approach to an economic evaluation of miner training. The findings of this trade-off analysis were discussed in the summary and shows that although the potential savings due to reduced injuries probably exceed the cost of training by a large margin, these costs represent such a low fraction of total cost of production that the economic incentives for safety training may be virtually non-existant. Economic incentive for training is to be found in the potent al for increased productivity from better skilled, better supervised, and by the same token, safer workers.

"SUBJECT" INVENTIONS AND PATENT APPLICATIONS

There were no "subject" inventions or patent applications in the work on this contract.

PHASE III INTERPRETATION

INTRODUCTION

General Finding

This research project can be divided into two distinct efforts. A survey of current mining training programs was conducted to produce a general description of the variations of training program characteristics. An evaluation of these training programs was performed to identify the variations of organization, course content, course objective, instructional methods, etc., that tend to be associated with low or improving injury rates. Strong indications of systematic effectiveness for some specific categories of training were found. The main evaluation effort used various definitions of effectiveness as the criteria for ranking mines according to the apparent effectiveness of their training in reducing accident frequency and severity. Because these evaluations found essentially all training program and training agency characteristics evenly distributed along the range of effectiveness scores, it is not possible to conclude that any particular approach is the best way to train miners.

Recommendation

In light of these general findings, a variety of training course objectives, training requirements, program organizations, methods, and safety regulations need to be implemented and monitored by the federal or state governments (and/or the mining companies, organized labor, or academia), that are based on the needs of the specific mine rather than some generalized "best" approach or method will be the most effective route to improve accident rates through training. The goal is safety improvement and should be approached by permitting and fostering a variety of training (and other means such as inspection and removing hazards inherent in equipment designs) whose specific objective is to improve mine accident records. Hence, training regulations (and the underlying standards) should be safety performance oriented rather than training oriented by specifying which specific courses are to be given and what duration, to whom, etc. These regulations and programs should also be flexible so as to readily permit changes over time so that as one cause of accidents is successfully reduced (e.g., by training, inspections, changes in operating procedures, etc., as was found to be the case for ignitions and explosions), the efforts that are devoted to providing training in this area are also adjusted to the need, so that greater emphasis can be placed on other areas.

TRAINING AGENCY ROLES

Mining Companies

Most of the present mining training programs covering both safety and occupational training and most of the personnel engaged in providing mining training are to be found within the mining companies.

Recommendation

In the interest of cost-effectiveness, maximum utilization of present resources, and also because employee training is properly the duty of the employer, the mine operator should remain the primary agency for actually providing training to the mine workers. This recommendation is not intended to preclude and/or minimize the significant benefits to be derived from the participation of other agencies in the development and execution of miner training programs.

Each mine seems to have a need for somewhat different training programs. Each mine needs different training resources that should depend on the company, mine conditions, mining methods, location, work force, composition, and many other factors. Present practices tends to base this need on meeting minimum requirements. The differences of need are generally reflected in the training plans that various mines submit to MESA for approval.

Recommendation

Each mine operator should prepare a training plan appropriate for the individual mine conditions, resources, etc. These plans should necessitate that each mine operator (or the responsible staff member) systematically identify training needs (e.g., actual and potential safety problems) and training solutions (e.g., training program organization, methods, etc.). The requirement to prepare a training plan that includes and is premised on demonstrated training needs and appropriate solutions should, in itself, go a long way toward eliminating training for compliance rather than safety. However, since the purpose of mine safety training is to improve safety performance and not to increase or maintain training levels or other aspects of the training plan, monitoring of training plan implementation (the means) should not replace monitoring of an individual mines safety record (the end). Inspection reports, which can provide an early warning of possible future problems are an important input to the training program planning process. Whether,

and to whatever degree, the achievement and maintenance of a good safety record is achieved by means of training, or a variety of other safety measures, is not materially significant so long as a good safety record and safe work practices can be demonstrated.

Our surveys have indicated that mine operator satisfaction with graduates of present junior college and vocational school programs, with new miner indoctrination programs, and with the apparent success of organizational development-type programs. All have two common elements. In upgrading miner skills, knowledge, and responsibility, the miners' behavior tends to become more "professional" as both safety and productivity benefits have been experienced. Also, the miners perceptions of the mine operator's commitment to and belief in these programs appears to be a key element on the success of these programs and in realizing the potential safety and productivity benefits. Although this is an over simplification of a very complex process, there are indications that if the miners believe that mine management is seriously concerned about the miners' health and safety, the training programs tend to be successful, and the health and safety records are better than if an adversary relationship is perceived. Conversely, if the training programs are motivated mainly by a need to remain in compliance with federal regulations, comparatively little return tends to be realized.

Recommendation

Much can be done to make future mining operations safer by increasing the understanding of future mine managers of the linkages between worker perceptions, attitudes, and work practices and both safety and production outputs. Present upper mine management must also be shown the potential returns of systematic determination of training needs and tailoring programs to the characteristics of their mines and workers in order to achieve more immediate results. The relatively small size of this potential student population and the potential near-term and lasting impact such a training effort could have, if successful, this approach should be given a very high priority. An information and demonstration program that presents to mine management, what can be done through tailored, output oriented training and safety programs in achieving improved safety performance without loss of productivity could be implemented by MESA or the Bureau of Mines. Showing mine management from the owner/operator to the foreman level how to improve safety and maintain (and even improve) productivity has immediate benefits that may exceed what can be achieved by federal concentration on training of instructors and miners. Concurrently,

mine management through the BCOA and other operator organizations could voluntarily publicize and support demonstrations of the potential for achieving safe, productive mining by use of non-traditional approaches to organizing the work and preparing the work force through training that is needed and desired by both management and labor.

Mine operators' beliefs about the supposed incompatability of safety and productivity can be altered and their perception and knowledge of how these goals can be reconciled and, even, be made complementary can be achieved by demonstrating success in the output oriented approach. If this is accomplished, the direct and indirect costs training efforts may represent a more attractive alternative to more and more government safety regulations and enforcement activities. However, if training is to have such a key role, mine management and organized labor as well as government all must accept and believe in its potential. The labor force must be successfully inculcated with a professional (rather than a hired hand) mentality. The isolated successes of approaches to upgrade worker roles and job satisfaction in mining and other industry indicate that there is much to be gained from their more widespread adoption.

Federal Government Role

The main roles of MESA in mine safety training, that emerged from the survey are (1) to define training standards through the promulgation of regulations and to monitor the compliance with these standards through reporting requirements, (2) to determine training needs and means for satisfying these needs through analysis of training and accident data and through the funding - in conjunction with the Bureau of Mines - of research and development activities, (3) to train instructors from all mines and miners from small mines that presently do not have adequate training capabilities, and (4) to develop and provide training materials such as manuals, and audio-visual materials and to otherwise provide assistance in the development and execution of training programs.

Recommendation

MESA should continue to define and ensure compliance with uniform minimum national training standards based on safety objectives so long as there is as major a mining safety problem as there exists today. For a number of historical and practical reasons many could be and are being carried out by the states through the testing and certifying of mine workers and supervisors. The direct MESA role in providing training to individuals

can be further reduced by fostering the implementation of a complete set of voluntary knowledge and skill standards to be conscientiously developed by mine management and labor through the vehicle of labor contracts.

Recommendation

When and if the mining industry is able to achieve a good safety record, the federal regulations record-keeping, analysis, and research activities will have largely fulfilled their primary purpose and should be deemphasized but not eliminated. Over a shorter time span, the training and certification of instructors, the development and provision of training materials, and the provision of other forms of training assistance will, hopefully, be aspects of the present federal program that can, in time, be totally transferred to other agencies. There will still be a great need for federal regulations, reporting and analysis, and government-sponsored research that supports the continued definition of training needs by mine operators and monitors the effectiveness of training efforts. Taking into a account present federal staff and funding limitations, it should be noted that the MESA training staff and program deserve some measure of recognition for having made excellent progress in using training (as one of several vehicles) for improving the safety of mining operations.

State Government Role

Not all states have mining training programs. The states that do conduct miner training have their programs linked with the state requirements for certification and qualification of foremen, new miners, mine examiners, shot firers, hoisting engineers, and mine electricians. Also included are programs dealing with mine rescue and first aid. None of the states are involved in the total training process that includes the conduct of safety training courses, training record keeping and effectiveness analysis, and the other training-related research and development activities that are engaged in by the federal government. The depth and quality of state mine training programs vary greatly with the most intensive efforts being those of the major coal producing states.

Recommendation

It is realistic to assume that, in time, state responsibilities in certain aspects of mining training will increase and federal activities will diminish in view of the following factors: (1) the

tates preceded the federal government in certain areas of mining training and seem to want to preserve their jurisdiction in these areas, (2) the federal government can provide funding to the states to initiate and supplement various training activities and (3) there are a number of general federal-state policies relating to which level of government should perform various functions that have been developing in recent years. It is also likely that if the federal government limits its role in providing actual instruction and training materials and assistance, some states might choose to become more active in these areas than they are presently. However, if the private sector (including both mining companies and other concerns whose business is one or another aspect of training) becomes the primary source for actual miner training and for the development and distribution of training materials; while the federal government is primarily responsible for national minimum standards, injury and training statistics, and research activities; the primary state role might best be the activities associated with instructor (as well as other mining personnel) certification or licensing. Licensing of a relatively larger number of job categories other than the ones presently covered by various state mining programs (e.g., operator's licenses for each separate type of mining vehicle) might be given consideration. It should be based on a system of state tests and/or satisfactory completion of state-approved operator skill and knowledge courses. Of course, this somewhat circumscribed general role that is envisioned for the states in no way precludes any state government from supplementing federal regulations, conducting actual training courses, etc., but the preceding recommended division of labor appears to be a logical tradeoff.

Academic Institution Role

A number of vocational schools, junior colleges, and organizations providing training services under contract to mine operators now offer mine safety and related skills training. Other than the training of mining engineers; the conduct of professional meetings, and research on mining problems including training concepts, the colleges and universities with mining schools are noticeably inactive in providing similar training. The academic institutions that do provide training offer courses that range from short courses on mandatory topics to associate degree programs. Mine operators often support these programs with funding and equipment.

Recommendation

The use of academic institutions by mine operators to provide the required mine safety (and other) training needs coordination and promotion by MESA because it is an approach that has several benefits. It often (though not always) means that the training skills of a professional educator (rather than a professional mine foreman, etc.) are being made (or can be made) available to the program. Secondly, this approach, in offering training at a centralized facility (as opposed to at each mine), can offer cost savings in that it can require less duplication of equipment, training and administrative devices, personnel, etc. Or, conversely, at equal cost, through more efficient use of training equipment, personnel, etc., it can mean that better and/or more resources can be brought to bear in providing mining training. Also, these institutions can provide mining training that is fairly well-tailored to local mining conditions, although it will not be as well-tailored as each individual mine operator could potentially make it. Tied in with this, however, is another potential benefit that there can be a cross-pollination effect, whereby personnel at one mine can learn from different approaches being employed at another mine.

Inherent in the successful use of academic institutions for miner training is the need for the schools to be centrally located within active mining fields with a large enough mining population to warrant the set-up of these programs within existing institutions or (less desirable from at least a cost standpoint) the formation of new schools. This geographical requirement is important so that the time and cost of miner commutation does not become a significant factor. Where this is not feasible, vocational schools, other organizations such as training contractors can still provide training by moving the instructor and/or the classroom to the mine site through the use of training vans. The pooling of resources that is inherent in the academic institution approach is the ideal training solution to the small mine operator's problem of providing adequate safety training.

Recommendation

The focus should be on establishing a superstructure for the provision of safety and skills training which can then be applied to the requirements for various professional and associate degrees. Many and varied approaches to using academic institutions already are being used that place the degree first and fit various MESA courses within the program as feasible. The real need is for a program that provides a miner with the operator skills and

and safety knowledge needed for the next job he aspires to in the mine. Such training programs, designed to upgrade both miner and supervisor skills and knowledge, would tend to improve both operational efficiency and safety performance. The incentive for miners to participate in these non-mandatory programs can be a combination of the miners job ambitions and company funding of the training. New agreements between labor and management with regard to job bidding and labor rates are needed. Mine operators may be reasonably expected to provide the funding for mandatory training regardless of its source. Federal and state support in the form of educational grants would predominate in the later stages of a miner's training where he adds theory to his practical skills and knowledge to gain a degree. In time a greater share of the advanced educational costs are likely to be assumed by industry once the value of these programs has been established and mine operators find it in their interest to provide such an incentive for miners to continue their education. The approach must be seen as part of a general upgrading of the mining profession. It will never work if labor perceives it as a scheme to turn all miners into company men.

Recommendation

The present college and university mining schools should be playing a more significant role in their education of the future mining professionals and managers by the inculcation of the need for safety awareness and in accident prevention techniques. By giving increased emphasis to these educational objectives in mining degree programs, an expected additional benefit would be a corresponding increase to academic research in these areas. Presently, a negligible amount of the total academic research effort is devoted to mining health and safety. The provision of extension courses in accident prevention techniques, mine safety program planning, etc., that are applicable to degree programs is another role for the higher level academic institution.

Equipment Manufacturer Role

Training in equipment maintenance and, to a lesser degree, equipment operation is a service available from most mining equipment manufacturers either at the manufacturer's facility or at the mine. Training materials are available that include electrical and control station mockups, and audio-visual aids. Personnel receiving this training at the

manufacturer's facility are often doing so in order to teach maintenance in the company training program. The basic training objectives deal with maintenance but safe and productive operation of the equipment is an underlying theme.

Recommendation

The underground mine equipment manufacturer's involvement in the provision of training services is not on a par with the services provided by non-mining heavy equipment manufacturers and could be improved. The training programs that have been offered at a few of the manufacturers' facilities are good, but these manufacturers do not feel that are in the training business. They provide a service received by too few maintenance personnel and virtually none of the operating personnel. The training provided at the mine site, usually at the time of equipment delivery, is even less satisfactory and, again, is not generally made available to each new operator and maintenance man. The provision of training for machine operators by more manufacturers is not the greatest need, although this would be quite beneficial if the manufacturers were to see training as a part of their business. The greatest need is for the development of good training programs, which are required not only for safe operation and maintenance of the equipment but, also, for better achieving the service potential of the equipment. Allied with this need is the general absence of complete operator and maintenance manuals. The ability of these manuals is a key to the development of adequate operator skill and safety knowledge training programs. Availability of training aids including mockups, films, and slides that could be loaned, leased, or sold to mine operators and schools plus periodic safety as well as maintenance bulletins would be highly desirable in the reduction of equipment related injuries.

Recommendation

Closely allied with the need for greater training services from machine manufacturers is the need for equipment design changes that would facilitate safe training as well as safer day-to-day operations. The Bureau of Mines has funded much research that has principally documented the machine operator's need for greatly improved human engineering of the equipment in terms of control identification, the provision of operational and maintenance displays, etc. There is also a great need to improve the quality of equipment maintenance through the application of basic maintainability engineering principles. To this end, various job performance

aids (e.g., operators and maintenance checklists log books, maintenance schematics, trouble shooting guides, etc.) need to be developed by the mining equipment manufacturers. Alternatively, but less desirable, by the federal government could pursue these recommended design changes and job performance aids. The objective of such design improvements and job performance aids is to improve the safety performance and facilitate the operational and maintenance training. The manufacturer's incentive to do more in this area is the better equipment performance and service that might be expected which will enhance the value of the maching.

Labor Union Role

The labor union (e.g., UMWA and SLU) have, historically, not had a major role in mine safety and/or operational training of individual miners. The United Mine Workers has been conducting training programs for its safety committeemen. There has been a related interest in training in other areas as reflected by negotiating for compensated training for the workers.

Recommendation

Short of a major contract change to obtain additional funding for training of miners similar to the means employed by the UMWA to obtain funds for the miners' welfare fund, it is likely that the unions will only have sufficient resources to undertake a very limited role in the overall scheme of mining training. However, this does not mean that a very important role cannot be performed by the unions. The training of safety committeemen (and other key union personnel), will continue to serve the workers' interests. Also, the union is in a rather unique position to obtain worker feedback of information on how to improve training efficiency and worker acceptance of training programs, to supplement other training efforts through promotion of safe working attitudes with programs for local meetings and through its publications, and to upgrade the workers' level of professionalism by fostering the worker's desire for educational self-improvement through permitting job assignments and wage rates to be tied to schooling and performance as well as seniority. This latter recommendation could potentially have the greatest and most long term safety impact of any other action. It could also significantly affect productivity, job satisfaction, etc. Training, testing, certification, etc., based on specific safety objectives should be central to this approach.

Trade Association Role

As was true for the unions, the trade associations (e.g., NCA and BCOA) have not had an important role in training and they still don't.

Recommendation

If the unions should continue to pursue training matters as an important goal in future contract negotiations, the trade associations should be prepared (directly or indirectly) to approach the training matter in a constructive fashion. One means for achieving this would be by conducting research studies among member organizations to help determine training requirements and cost effective methods for achieving the training goals. Also, the trade associations are in a unique position to act as a clearinghouse for the collection, pooling, and the dissemination of information on training programs, training methods, the effectiveness and costs of different approaches, etc., by sponsoring meetings and through publications. In differentiating between conducting research and acting as a clearing house, the difference is one of degree rather than function. The more active role of conducting training research and development would entail a greater funding and staff commitment and would tend to benefit all the members in a cost-effective manner. The more passive role of acting as a clearinghouse would be of greater benefit to the smaller operators (who most need the assistance) and would be more dependent on the cooperation of the larger operators who have developed some comparatively excellent training programs at their own expense. For example, the somewhat similar accident prevention and management training programs that have been developed somewhat independently by U.S. Steel, Bethlehem, Consolidation, Island Creek, Peabody, etc., could immediately be of benefit to many (if not all) of the small mine operators if the larger operators were inclined to provide the small operators with this expertise, either with or without a cost consideration through the BCOA. Such activities on the part of the trade associations, if handled in committed fashion, would shift these organizations away from the current position of reacting to proposals or demands from the federal government and the unions to initiating training objectives and needs that are in fact cost-effective and do not artifically isolate safety from production skills. Such programs would undoubtedly be more palatable to mine management than more and more federal programs, contractual provisions on training etc.

SAFETY TRAINING OBJECTIVES

Accident Prevention Courses

The strongest statistical evidence that mine safety training leads to reduce injury rates was found for the training in the specific (e.g., roof and rib fall, haulage, electrical, and machinery) accident prevention categories and to a lesser degree the general accident prevention category. This corresponds to the opinions expressed by MESA and mine operator training officials. This training is being stressed by MESA in the mines having the highest injury rates and is the heart of several company-developed safety programs.

Recommendation

That the accident prevention form of training is the most effective in reducing the frequency of accidents is not surprising when looked at from the viewpoint that it is the only approach to mine safety training course that has the exclusive objective of reducing injury rates. There seems to be little doubt, based on our findings as well as government and industry opinions and current practice, that increased accident prevention training is warranted and productive. Two basic types of courses are required; (1) training in the techniques of identifying and eliminating hazards and (2) training in the prevention of specific, job-related accidents (e.g., for continuous miner and roof bolter operators, for shot fires, etc.).

In spite of the recognition that accident prevention is a desired training objective, the various courses in accident prevention are a relatively small portion of the total reported training effort (about 5 percent) in the data that were studied. There are two reasons for this. Much of this training is part of more comprehensive MESA and company safety programs and hence, is not reflected in the reported training statistics. This training, except for ground control and electrical qualification courses, is not mandatory and so it is neither conducted nor reported at as high a rate as is apparent for the mandatory topics.

Recommendation

In order to accurately assess the present baseline level of accident prevention training being conducted, which is an essential prerequisite for determining how much of an increase in the amount of this type of training if warranted, the level of

this effort must be assessed by either a special study, which would produce the quickest answers at the lowest overall cost and/or by a change in the reporting system. This latter approach would take a long time to provide answers, but is probably necessary, even if the special study is performed, to properly monitor and assess mine safety training efforts by all sources of training.

Once the question of how much more accident prevention training is required is answered, the next step would seem to be to ensure that this type of training receives more attention. As will be seen from the following dicussion, not all of the increase in the time devoted to accident prevention training must necessarily come by increasing the total amount of time devoted to mine safety training. Some of the other forms of training and training program administration can be deemphasized with increased emphasis (and time) available for the accident prevention objectives.

Electrical Qualification Courses

An average course duration of 50 hours for electrical qualification/requalification (which represents 50 percent of the total mine safety training program effort) makes the course-hours and level of effort in this category very high relative to the percentage of electrical-type injuries.

Recommendation

It is dangerous to suggest that the level of effort being devoted to electrical training may be reduced, especially since there is a strong positive indication that the present form and level of training (which includes large dose of theory and skills objectives as well as safety components) is effective in keeping the injury rates low (relative, only, to other types of mining accidents; not necessarily other industrial situations). However, at least in relative terms, this may still be viewed as a possible case of "over-training." This point is premised on the thesis that if there is a finite limit to the total amount of training that can be provided (for a number of reasons) and if there is a greater need for other types of training and/or for training in other course areas (because of higher injury rates and higher demonstrated measures of training effectiveness), this is a course area where there appears to be some latitude for a reduced level of effort.

For this change in emphasis to be acted upon, several routes are available. Ideally, any efforts being devoted to further elevating the requirements for electrical qualification (in terms of improving training, testing, etc.) should be terminated, but not at the price of lower requirements (and more accidents) if at all possible. If, however, a tradeoff is required, then electrical training represents a prime candidate for reduced levels of effort, so long as equal or greater levels of effort are then devoted to other, higher priority areas. The prime agency for effecting these changes would be the government (in terms of defining the qualification requirements, the training provided, and/or the tests that are administered), but mine operators also have a certain amount of control in bringing about any immediate change in emphasis.

First Aid and Mine Rescue Courses

Training in the categories of first aid and mine rescue also represents a large portion of the total reported training effort (i.e., 26 percent), even though this training does not directly address accident causality and prevention. The objective of this training tends to be the reduction of injury severity once accidents occur. The data does not show that this objective is being attained even though it is of secondary (but still significant) importance. However, this training is mandatory leading to approximately five times more effort devoted to reducing accident severity then is devoted to reducing accident frequency.

Recommendation

These observations are not intended to detract from the value of and need for training to deal with mine emergencies. The danger is that these courses have a widespread identification with safety training, where the concept of safety does not go beyond the problems resulting from accidents, rather then dealing with the problems that cause accidents. (The first answer to questions about safety training in any organization from a mine to a scout troop will often be that first aid training was given recently or is scheduled for the near future). These skills and knowledges are needed, but it is necessary to recognize that they can be accorded undue emphasis, at the expense of the accident prevention approaches, because of this attitude.

Recommendation

Hence, in this case, a change in perception is required first of all. Secondly, any efforts being devoted to further improving first aid and mine rescue training should be reconsidered in view of the fact that the current training is unrelated to injury severity. In contrast to the recommendations made with respect to electrical training, these course areas are not good candidates for any reduction in the actual level of effort being devoted to day-to-day training activities, testing, etc. Effecting the perceptual change is an excellent example of one training goal that should be included in any mine operator training program. The second aspect of this recommendation regarding further efforts to improve first aid and mine rescue training implies that additional research is needed to confirm that severity is currently unrelated to first aid or mine rescue training efforts and to better understand how this training can be made to have the desired impact on severity.

Mine Ventilation and Explosive Atmosphere Detection Courses

Training in explosives safety, mine ventilation, and methane detection categories is more difficult to evaluate. The catastrophic nature of some explosions or ignitions make it easy to recognize why these categories of training represent 15 percent of the total reported training hours. The fact that this type of injury was infrequent in the data analyzed indicates that the training may be achieving the desired result.

Recommendation

Although a very high measure of training effectiveness would seen apparent in this area of mine safety training that might be used as a basis for a claim of "over-training," the relative level of effort being devoted to this training area is fairly low. Also in the cases where both injuries and training have assumed the training tended to have been ineffective and in some cases non-existant. Hence, the mine ventilation/atmosphere testing training category is probably at or near an optimal level of equilibranting maximum safety performance and minimal, but effective, training effort. While no change in training approach or further efforts for course development appears needed at this time the administra-give procedures for the large number of short courses could be improved to reduce the effort involved as well as make it easier

to monitor for compliance with the minimum standards.

Mine Law and Safety Program Administration Courses

Mine law/safety program administration training represents about 4 percent of the total training effort. Because of the general nature of these courses it is impossible to assess their effectiveness in terms of reducing accident frequency and/or severity based on the data that were studied.

Recommendation

If provided to the average miner, relatively little benefit will generally accrue from these courses. Since, however, these courses receive so little effort even though they can serve a "useful" general indoctrination function, some change is recommended. Since the trainee is the safety specialist, mine manager, and mine foreman, a greater benefit potential may be expected if the procedures for determining training needs and evaluating training effectiveness were stressed.

Course Development and Dissemination

The various training agencies, in aggregate, have expended a significant amount of time in developing a wide variety of courses. Other than the fairly wide distribution that has been made of "approved" training materials furnished by MESA (e.g., manuals, booklets, slides, films, etc.), much of this material is not generally available to most of the mining (and training) community. Large segments of this community do not have the resources in either funds or training personnel to duplicate this material. For the segment of the community that does have the resources wasteful duplication of past efforts would be made if everyone were to independently redevelop these courses and materials.

Recommendation

Recognizing that much of these materials may suffer from a variety of deficiencies including poor quality and/or being too parochial to be of immediate general use, they still represent at least a very valuable starting point for further course development. Many of these materials, being "better" than nothing at all in some cases, would be of some immediate benefit to a number of small mine operators. An effort should be made to locate these materials (the existence of some of the better courses

is already widely known), evaluate them, organize them into typical training session length modules (1 to 2 hours), and disseminate and/or encourage the dissemination of these materials which could then be readily used as appropriate. Some of these materials (e.g., mine company-developed accident prevention courses) would not necessarily be readily available for dissemination to the general mining community without some form of "compensation" accruing to their originators who may feel that they should be able to recapture (in one form or another) the investment represented by the developing of these courses. Monetary recompense would be required in some cases, but some form of recognition for the service being performed by making these materials available is likely to suffice in a large number of cases.

If one agency needs to take the lead in this undertaking, MESA would seem to be to be the best choice, at least from the standpoint of being best equipped for performing the dissemination function. The location, evaluation, and modification functions could be a logical extension of the current activity of the Holmes Safety Association. Examples of materials that might be of most immediate use and/or suitable for immediate dissemination are given the following listing of agencies and course types:

- Mining companies (courses in accident prevention, equipment operation and maintenance, management development and new miner indoctrination
- State Governments (course materials for occupations that require certification and new-miner indoctrination)
- Academic Institutions (occupational courses for management, equipment operation and maintenance, and new miner indoctrination)
- Equipment manufacturers (courses for equipment operation and maintenance)

TRAINING EFFECTIVENESS

Perceptions of Need: Commitment and Relevancy

The aggregate data and insight into the training process that was gained during the survey all point to the conclusion that the effectiveness of the training depends on the perception of the need for the training and the skill with which the available resources are applied to the perception of the need for training. When this need is limited to doing only that training required by law (or the parent company) the training is not likely to produce very much more than the required record-keeping paperwork. On the other hand miners seem to respond positively when they participate in programs they see as the result of the supervisors and local mine management's commitment to their safety and to maintaining safe working conditions. Although a primary training skill and mining knowledge must be successfully demonstrated by instructors who are provided adequate resources to establish relevancy in the view of the miner being trained, the fact that the primary goal of the training is that safety must also be apparent if both the miner and the company are to obtain the results desired from the training.

Recommendation

The earlier recommendation that training plans should be based on and monitored against safety performance must, therefore, be conveyed to the student in the classroom and must also be reenforced (e.g., made believable) by management policies that demonstrate management (and government) commitment to this safety goal in the mine on a day-in-day-out basis. An example of this type of commitment to the safety objective of training is the use of formal "safety contacts" by foremen that are monitored by top management with the same diligence that is devoted to production figures. Other approaches are also available to mine management such as showing miners the trends in time and funds devoted to training along with feedback on the safety results being obtained. Anything less than a concerted demonstration of management commitment tends to result in a lot of wasted time and money.

Recommendation

The earlier recommendation that training programs should be adapted to the particular hazards involved in each mine and job should be reinforced in the classroom and in the mine to demonstrate that the training is relevant to the miner being

trained. If the relevancy is not demonstrated again the training effort will be largely wasted. The time-tested use of accident statistics and descriptions of past accidents are examples of ways to demonstrate relevance. Another more modern example is the use of job (task and hazard) analysis techniques, especially when performed by the individual miner for training in how to recognize potential hazards and hazardous work practices. Training a foreman in how to prevent accidents and how to reduce their severity if an accident should occur and then expecting him to train his men in a common practice that may not be working unless the foreman is assisted by scheduling time for training routinely and provided with material and personnal support. Here, too, relevancy must be taught both in the classroom and on the job even though the work place may be the most relevant classroom.

Methods Effectiveness

As stated earlier, the course areas in which safety training is provided and the methods by which this training is carried out are not as important in determining the effectiveness of the training as the way in the training resources are developed and used. In essence, the most sophisticated training methods such as closed circuit TV, simulators, programmed instruction, etc., will not ensure effective training through safety performance. Conversely, in the right environment where management commitment and relevancy is demonstrated and perceived by the trainee, the application of quite redimentary resources can be highly effective. However, it cannot be denied also that a combination of a good training environment and good training methods will produce the most effective training programs.

Recommendation

Present efforts to upgrade, monitor, and certify instructors to produce and provide training manuals, booklets, slides, films, etc., to develop training aids including training systems and teaching machines, and to develop new courses in accident prevention and in the safe operation of different types of machines are all important and should be continued. However, their potential contribution to training effectiveness will not be realized until the environmental problem is adequately addressed and, ultimately, solved. Therefore, a change in priorities, at least for a while, to deemphasize the what, who, where, when, and how of training, and to get all parties to accept why the training is being used, is imperative.

TRAINING METHODS AND RESOURCES

Instructors

Once decisions have been reached on what safety-related courses need to be taught and what substantive areas should be covered in these courses the next most important consideration is the instructors. The training and certification of instructors has done much to improve this aspect of training. There is, of course, always room for further improvement in the various factors that determine the quality of instructor personnel. The greatest problem relating to potential instructor effectiveness is not that the instructor personnel lack suitable backgrounds, but that they often are not "enabled" to achieve their potential. For example, foremen who are certified as co-op instructors have the basic experience and knowledge and are more-or-less adequately trained to be good instructors. They are, however, often too busy with other duties to do an adequate job of training. Review of the actual number of instructors being shown in reports of training in these cases also indicates that certification of all foremen as instructors may really be a goal rather than the practice. Mine management may easily indicate by the priorities set formally, or by less direct attitudes, that the training function is not highly regarded, or is only being performed to remain in compliance with the law. Hence, the instruction that is provided is often, largely, a waste of time or, at least not nearly as effective as it could be for the amount of time being spent by the instructors and miners in direct instructional activity.

Recommendation

A general preference for the continued use of mine company-employed co-op instructors was expressed earlier based on cost effectiveness, their knowledge of an individual mines condition and problems, also, continued instructor training and certification has merit. Further, improvement of the instructional quality of these programs is not a high priority need, but something must be done with regard to mine company selection and/or government acceptance of students for these programs. Requiring that co-op instructors be employed full-time in this capacity may be one (though possibly an extreme) approach. An earlier recommendation with regard to the information and demonstration activity directed at mine management may suffice to "enable" the instructors to perform effectively, if it is successful in achieving the goal of eliminating the perceived (and, hence, often real) conflict between safety (and training) and mine production.

Recommendation

Transfer of instructor training and certification from the federal government to the states was mentioned earlier, but is not premised on improving instructor effectiveness. However, irrespective of whether this function is to be performed by either the federal or the state governments, there is a need to improve instructor compensation, and possibly staff levels and work conditions as well, in order to remain competitive with the mine operators in the hiring of good qualified instructor personnel for these programs. Levels of compensation for mine company and vocational school instructors, however, did not appear to be a problem.

Recommendation

A certain but limited tendency to think of the use of various training materials and aids (e.g., video tape and programmed and computer-aid instructions) as a substitute for, rather than an adjunct to, the use of qualified instructors should not be permitted to develop further.

Recommendation

Finally, our findings have clearly indicated that a low ratio of employees per instructor is a key element in achieving effective training.

Training Materials

Training materials used in mine safety training vary widely in type, scope, content, and quality. Types of materials include training manuals, booklets of various types, wall charts, slides, films, and videotapes. MESA (formerly the Bureau of Mines) is a major developer and supplier of these materials. Several of the state mining departments produce text books, study guides, and other materials for training courses that prepare miners for state certification exams. Mining companies produce a large amount of their own materials; often adapting and/or employing materials obtained from a variety of sources. Academic institutions and equipment manufacturers generate much of the materials that they employ.

Recommendation

MESA should continue in its efforts to develop and disseminate training materials and, in keeping with other recommendations,

should broaden (as is presently planned) and adapt materials developed by other agencies. MESA generally packages these materials as complete courses, but a modular approach would appear to be more useful to at least some of the users, who are using both parts of MESA materials and locally prepared materials in their programs. For example, formatting the training manuals to readily permit interleaving of other materials and publishing the manuals unbound and punched for insertion in notebooks would enable the users to more readily adapt these materials to their particular needs. Also, by fostering modification and adoptation of these materials, the degree of relevancy is increased. Furthermore, there are reports that where the miners become directly involved in the process of developing the details of the training program this involvement has brought as much of a safety benefit as the eventual training itself. Packaging manuals, slides, etc., in smaller more discrete lots with different versions available for different seam conditions, for different machine models, and for different mining methods or mining plans will allow greater flexibility in tailoring materials and enhance miner identification with and transference from the material to his own mine situation.

Once these materials are modularized, not only are they in a better form for inserting materials from other sources, but also will be easier to update. Short discrete topics focused on a particular accident cause could then be easily used for "spot" correction of situations disclosed by inspection or an accident in routine safety meetings and other training functions as soon as a particular safety problem is discovered. Finally, once these materials are made more flexible and the mode of their use shifts to being particular solutions to discrete safety problems, use of these materials (e.g., for and by MESA inspectors) can be promoted through a periodic newsletter to permit new and novel ideas to be widely disseminated throughout the training community.

Recommendation

Training films and videotapes are highly useful in many more areas of training then are currently available. Because the cost of producing these visual materials is higher than for developing training manuals, booklets, and slides; and because the audio-visual materials warrant a significant amount of effort

in terms of coverage and quality; films and videotapes should not be given a very high priority now. However, films and videotapes can potentially offer improved instruction by providing visual demonstrations of mining operations that can often be more instructive than first-hand observation, and by being a means of maintaining student interest through variety in the mode of presentation or increasing the topic's so-called entertainment value. Therefore, audio-visual materials are worthy of receiving more attention to complement the modular packaging and use of other materials. In terms of being able to efficiently improve instructional quality and safely convey certain types of materials, films or tapes are easily the best means available.

Recommendation

The development of self-paced training guides, with self-test features, has some merit and should be considered for use in various training contexts, as an option that can be made available to individual miners who are interested in self-improvement, and as a lower-cost, but generally less effective alternative to the use of teaching machines. Once MESA has more-or-less completed the work that it has undertaken in attempting to publish a complete series of training manuals, these manuals can be reformatted as programmed instruction guides for use by miners who are not able to engage in training programs in the classroom or workplace setting.

Training Aids

Training aids of various types are widely used in mining training, but not to the same extent or degree of refinement that they are used in some other comparable training contexts such as vehicle operation or military "team" training. Slide, viewgraph, and film projectors are in wide use and closed circuit TV is beginning to be used more widely by both MESA and the large mining companies. Dummies for first aid training, small scale mine models, some whole-or-part-equipment models (and/or actual hardware), various types of full scale mine simulations, etc., have been in fairly common use. More recently, government-funded research has been focused on developing various training systems (e.g., a full-scale, simulated shuttle car trainer that is similar to the systems used to train high school student to drive an automobile) and teaching machines (e.g.; a computer based system for

imparting information, evaluating the students mastery of the information, and gearing the training to the individual student's learning skills.

Recommendation

The effectiveness and cost-savings of various teaching machines has been demonstrated in a number of different training and educational contexts. From this standpoint the government-funded development of these training aids as a means for improvement training effectiveness, should be continued. However, present expectations with respect to the potential benefits of these devices, in terms of cost effectiveness, may be too high. The teaching machines should be viewed as adjunts to the instructor, as a means for individuatizing the training, and as a time-serving device for freeing up the instructor's time so that he can give individual attention to trainees requiring his help; not as a substitute for the instructor. Since their capital cost can not be wholly traded off against the cost of using instructors and the initial investment in these devices may appear to be high (when compared with the present investment levels that mine operators are used to making for training equipment), the potential size of the commercial market for these devices is small and, hence, the market price may never be very favorable. MESA (and the Bureau of Mines by sponsoring the development), along with academic institutions and state mining departments, represent the existing market for training machines. Hence, although these devices promise improved training, they may well never represent a cost-effective means of training unless they are designed into a training context that will provide high rates of utilization. The training requirement and concept for application of training machines should be taken into account when programs are being planned for developing these devices for mine safety training.

Recommendation

The case for and against training systems is similar, but differs in certain aspects and degrees. Effectiveness of simulator systems (and even actual cost-savings) has been amply demonstrated in a number of instances and, hence, government-funded development should be continued even though, again, the expectations attached to these devices may be too high. They are an effective means of providing training in the operation (and even maintenance) of machinery; they offer a safe means of

providing training in that hazardous conditions can be simulated, and, hence, student errros need not lead to accidents; and, if the fidelity of the simulation is high enough, they can represent an almost complete substitute for other means of training in the production setting. Since their capital, operating, and maintenance costs can be lower than the dedicated use of actual production equipment, they are not only a potentially more effective and safe substitute, but also potentially more cost-effective. Where production equipment is not being significantly removed from its primary productive use, training systems can frequently represent a sizable additional capital cost. Few mine operators have a constant enough need for simulation systems and, hence, their market may again be largely restricted to the federal and state governments and academic institutions. Since these systems represent an improved and safe substitute for the use of actual equipment and can be more cost-effective, they should be given a higher priority than are teaching machines. This recommendation considers the fact that the two types of devices serve quite different functions and that the size of the market, if not the extent of the use, will be quite limited.

Recommendation

In terms of facilitating and promoting the use of other less sophisticated types of training aids, very little investment would be required to realize significant improvement. Much could be achieved by the mere dissemination of ideas. For example, one instructor got miners to willingly use eye protection equipment by holding and displaying safety glasses in one hand and offering them a choice of the glasses or the alternative - at which point he removed a glass eye from his pocket and rolled it out on the table. The technique is but an example of the use of a simple, effective and inexpensive training aid which was not soon forgotten.

Also, the wider use of mine models (not only for training, but for planning and operational purposes as well) could be easily promoted by the development of inexpensive, scaled model kits and manuals to show all the ways these training aids could be used. Furthermore, the use of above-ground mine simulations for training purposes would be readily promotable by the publication of a how-to manual that described the benefits of these simulations.

Lastly the effective use of hardware components in training could also be enhanced by the dissemination of ideas, such as how components can be used to inexpensively fabricate hardware mockups or displays for operator and maintenance training. The equipment manufacturers (themselves or under government contract) assemble training aids from existing components and market them. More of this is possibly by adoption of off-the-shelf components, so as to make them more effecive for use as training aids.

Recommendation

Finally, the equipment that is available for presenting visual materials can not always be cost-effectively used because the quality of many of the films and videotapes that are available for training purposes is highly variable. However, many users might well consider investing in variable-speed, stop action movie projectors (and other similar equipment that is available on the market) which can be very effectively used in training to highlight certain points. Similar comments could be made about the use of automated slide/tape recorder systems which have a more limited utility in training.

Motivational Techniques

The use of motivational techniques in mine safety training can be divided into two groupings; intrinsic and extrinsic rewards. Extrinsic rewards (such as giving prizes and awards for good safety records) have long been used and are often pointed to as evidence of a strong management commitment to safety. Instrinsic rewards (such as the improved safety performance that results from instilling and reenforcing how certain mining hazards, lack of caution, or unsafe work practices can lead to disasterous results) have long been used as well.

Recommendation

One would think that the intrinsic safety reward of a miner's maintaining his own health and safety is the strongest possible motivational force. Such a force exists, however, only to the degree to which the miner, (1) believes he is in a dangerous environment, and (2) believes he can protect himself from that environment through safety conscious behavior. These factors are operating presently, but can still be further enhanced by increased efforts to demonstrate that mining accidents are avoidable.

A cooperative, demonstration program conducted by MESA in conjunction with one of the mining companies, would be one way to determine whether, and at what cost, such an increase in safety performance can be achieved and would be successful in terms of cost-effectiveness and worker-management endorsement. This approach would be the best means of motivating and promoting improved safety and safety training at other mines. Also, the Hawthorne effect that might be expected to operate in such a cooperative program (when compared with the, presently, more coercive approaches) would help to improve the chances of such a program being successful.

Other techniques that are presently in use, but are capable of achieving better results if applied more assiduously at the mine and section level, are the increased use of accident statistics and analyses in training and day-to-day operations, wider dissemination of fatalgram-type information (e.g., through posting on bulletin boards and by news releases to local papers, TV, and radio stations), and the use of safety contact-type feedback from supervisors and peers to provide recognition of good safety performance and reproach for unsafe work practices. Similarly, in the actual training itself, the use of tests to provide immediate feedback increasing the levels of trainee participation rather than demanding mere attendance, and other steps that have been recommended (to make the training more relevant, demonstrate management commitment, make the training more stimulating and interesting and thought-provoking) will all serve to improve safety training, as well as job safety performance.

Recommendation

Extrinsic rewards (such as prizes and awards) are too far removed in time (and often in significance) to the individual miner to be effective motivation of day-to-day behavior. However, as a means of offering recognition to the miner who has work safely this motivational technique has some merit for publicity purposes and as a way of indicating management concern for safety. The use of prizes and rewards in education is widely practiced and might have limited utility and merit for increasing safety training performance (e.g., based on test performance). However, using safety performance as a criterion for promotion, or in an incentive pay scheme (which might be costly), might be more direct and effective motivators. Conversely, of course, many

unsafe performance as the basis for demotion and docking of pay are also logical possibilities, but ones that would be more difficult to implement.

Recommendation

Finally, a conscientiously and fairly made, enforced, and publicized policy that unsafe work practices and deliberate violation of safety standards would be grounds for immediate dismissal for any miner, supervisor or staff/management personnel would leave little doubt about mine management commitment to safety and it would inevitably increase the amount of thought and attention devoted to safety matters by all mining personnel. Such a policy clearly is an extreme measure, is a punishment rather than a reward, and requires full labor support. However, if administered with the necessary safeguards, could mean at least temporary loss of income to an individual that can be considered a tradeoff against his very life and possibly the lives of others.

Classroom Instruction

Classroom instruction tends to be the predominant mode of instruction for most of the formal mine safety training. Of all the training sources, the mining companies tend to provide the largest amount of both formal and, most naturally, informal instruction.

Classroom instruction offers several benefits, including having the trainees and instructor together in a locale that has various paraphernalia (e.g., chairs, blackboards, etc.) required for in the instruction and being at least somewhat isolated for the distractions of the workplace. In contrast, this traditional separation from the workplace also places certain limitations on the training that can be provided, such as the non-availability of the actual machinery that the miner will be using. Most important is that all-too-often the behaviors, skills, knowledges, and attitudes that are "learned" in the classroom instruction often has been wasted. Based on the preceding points one may conclude that classroom instruction does not fully satisfy all the requirements for training miners to work safely (or to operate equipment productively). Therefore, although the continued use of classroom instruction is warranted, increased use of formal field instruction is required, both in lieu of and as a reinforcement to classroom instruction.

Recommendation

Since many of the other recommendations pertain to various elements of classroom instruction, little need be said here except that one major fault of much of the present, formal classroom instruction is that it is too theoretical. This type of instruction does tend to "educate" the trainees and is beneficial. However, if the main objectives is to eliminate or drastically reduce unsafe modes of behavior, then the personnel providing the training (and designing the courses) must keep this objective in the forefront where it belongs. After the students are provided a basic understanding of the hazards involved and the potential consequences, the emphasis should be placed on training the miners in specific, safe job practices.

Field Instruction

Field instruction, as it is being defined here, encompasses a wide variety of training methods. One end of this range is represented by informal on-the-job training, where the "instructor" is a journeyman or a foreman who, without the benefit of training paraphernalia, is attempting to show the trainee how to perform a specific job in the production setting over a variable period of time that generally ranges from minutes to weeks. The training may be continuous for a specified duration (or in the training unit concept) intermittant (on an as-required-basis) in the course of the normal work routine. More formal forms of on-the-job training include structured, planned "safety contacts" made by foremen in the course of the normal work activity; section safety meetings conducted before, during, or after the shift; and the use of homework and check lists to supplement and guide the instructor. There are also training unit or section approaches to providing structured O.J.T.-type instruction in a working section of the mine with normal foreman-to-miner ratios raised to permit the training objectives to be satisfied. Other non-workplace forms of field instruction include instruction provided at the portal of the mine; in the bath house; and at simulated workplaces designed to teach the miners the desired skills, in a controlled manner without interfering with production.

The extent to which and the effectiveness with which these various forms of field instruction are used by various mining companies varies widely, but one or another of these forms of instruction is employed at every mining operation. Although other training agencies may use field instruction to some degree, generally they tend to rely more heavily on classroom instruction, and in some cases they employ no field instruction whatsoever.

Informal OJT

Informal on-the-job training, which is basically nothing more than the combination of the traditional apprenticeship system and the normal functioning of the foreman-journeyman work relationship, has been used for years and is still being used in virtually every mining operation in the country. However, this form of training, even though held in some regard by mine management, is largely in disrepute in training circles. While it can be maintained that training professionals would tend to derogate OJT because it is in their professionals self-interest to do so, it is also equally true that a sizable segment of mine management is almost totally unaware of the time costs (let alone the lack of cost-effectiveness) of informal OJT.

Informal OJT benefits include the "facts" that OJT is often one-to-one training representing in some respects the training ideal, that the costs "appear" to be low, that a professional is training students to perform a particular job in which the teacher is expert, and that there is an interaction of production and training with virtually total transference between the job and the training. On the debit side, however, much that appears to be superficially attractive and beneficial does not hold up to close scrutiny.

The one-to-one teaching ratio is attractive, but much is gained in terms of increasing the effectiveness of training by (student-student) peer interactions that are lost in most informal OJT one-to-one interactions. It is also much easier to facilitate (student-teacher) peer interactions (in terms of instructor selection) when a twenty-to-one teaching ratio exists. These potential benefits are not given adequate consideration. In other words, if through some identity between age groups (or other individual traits) some identification and communication can be facilitated between student and teacher (and/or within a group of students), the chances of achieving true "learning" and integration of the training materials are increased. All this means is that where there is a generation gap (to use common parlance), as is true in most informal OJT and much traditional trainings, there is a certain bias against achieving effective training. When through capitalizing on more favorable student-teach ratios, one can take a young but somewhat experienced miner and train him to be an effective instructor, experience has shown that effective training most often results. The foregoing discussion is not highly theoretical. It is supported by wide experience both within the mining industry and from other training contents. In summary, having an "old dog" train a new miner or even train an older miner in a new skill area, is not necessarily the most effective approach.

It is also not true that informal OJT is the least costly approach. When one considers (1) the "true" costs of having normally one instructor per student (at least at any one given time), rather than one instructor for a number of students, and (2) the largely hidden costs (which are almost totally ignored) of decreased productivity and/or the amount of totally lost time that may or may not be charged to training, the "apparent" costs of a formal training program (which always appears as a separate, and hence more noticeable, line item) tend to be dwarfed by the "hidden" costs of the informal OJT approach. The disparity, in favor of a formal OJT approach, becomes even more apparent (in favor of formal training) when one considers cost effectiveness rather than pure cost alone.

To say that almost any professional roof-bolter is a good roof-bolter instructor is almost totally false for a number of reasons. While the real-world experience in that job is a major prerequisite, knowledge and experience in training skills can be of equal or greater importance, as can the aforementioned age and other related factors. Hence, to have an "expert" roof-bolter, but a totally "inexpert" instructor providing the training can be very cost-ineffective. Trying to impart training skills to "experts" in each and every job classification also lacks cost effectiveness. Finally, training supervisors, who are (presumably) expert in many areas, to be instructors is not cost-effective because their main functions and performance evaluation criteria are to be supervisors of production not instruction.

Recommendation

After some thought and honest analysis, it becomes clear that the most effective approach is to use a totally (or almost totally) dedicated training staff (of training specialists) who also, through work experience, happen to be capable miners in one or more job classifications. This approach is made cost-effective by organizing the training contest to make the requirement large enough to achieve optimum utilization of this staff in an active training role.

Another closely-related factor is that, in informal OJT, where the instructors do not receive special training, there is an unfortunate tendency toward the "experts" imparting bad, as well as good, work practices. There is little or not control (and often inadequate awareness) of the tendency to impart dangerous "short cuts" that may not represent a hazard to the experienced miner. This represents a particular hazard of informal OJT. The neophyte trainee all to often learns the short-cut,

but not the other skill and knowledge that have permitted his instructor to get away with a unsafe mode of behavior for years. Hence, it is the trainee who so frequently becomes injured or killed. If not closely supervised, which is often the case in informal OJT, the trainee manages to make all his mistakes and use of any acquired bad habits in an environment where they are most likely to be harmful. This is certainly not cost-effective training.

Finally, the "apparent" intertwining of production and training, as stated above, does not stand up to close scrutiny. The high degree of transference of training to the job is not cost-effective if unfavorable behaviors are being transferred. Finally, equally high levels of positive transference are achievable through other training methods and with a higher degree of cost-effectiveness based on the use of more favorable student-teacher ratios.

Recommendation

Informal OJT should be finally laid to rest. In the comparatively limited number of instances where a very small mine company is involved and/or the training is in such a narrow specialty area that only one student is to be trained and, hence, the development and execution of a formal training program is not warranted, then other recourses (e.g., outside training) should be pursued in preference to the use of informal OJT.

Recommendation

Where OJT must be used, upgrading the quality of this form of instruction is required. This type of training needs to receive the same degree of attention and warrants as much management control as any other aspect of the safety training program. By formalizing this type of training through institution of OJT curricula, having trained instructors follow-up on classroom instruction by providing the final training performance evaluation, and record-keeping in the workplace to keep the trainee and his supervisors aware of skills and level of training progress can accomplish much. Whether OJT is the final step in the training process, or represents the total training process the present ineffective forms of informal OJT can be transformed into effective, formal OJT programs by systematically planning and executing these programs. Management concern, commitment, and monitoring (or initiation of program design and execution will be one of the

key factors, if not the key factor, in the success of these programs.

Recommendation

Formal on-the-job training frequently encompasses such training methods as the use of a quota of periodic "safety contacts." Wherein foremen, having observed unsafe job behaviors that require immediate attention, systematically and immediately provide on-the-spot training. Foreman then carefully monitor and keep records on the individual miner's job performance and training. Periodic section safety meetings are held when the forman, having determined that safer work practices may be instituted on the job, carefully prepares a mini-lesson to train the miners in the use of the revised work practices. These forms of formal OJT generally pertain to day-to-day mining operations and problems, and differ from informal OJT in that they are carried out in a systematic, preplanned fashion; the topics being covered are fairly limited in scope; formal evaluation and record-keeping procedures are employed; and the foreman (who receive formal training in the use of these techniques) are monitored and assessed by upper management in their performance of these regular duties, just as their production records are reviewed and evaluated. Safety and Training staffs, where these exist, also provide and/or assist the section foremen in providing formal OJT, determine and/or recommend safety topics for use in safety meetings. These structured, planned forms of OJT are an essential and necessary part of any mine safety program and their role in supplementing other elements of an overall safety training program must be recognized and carefully controlled by mine management.

Training Sections

Another type of formal OJT, which is infrequently used but which merit, is the use of an "operating" training section where normal production goals are suspended and normal foreman-to-miner ratios are increased to permit effective training to be carried out. These sections provide training in all aspects of section operations, starting with class room instruction and gradually working toward "normal" production operations, so that when a trainee graduates from the section he is fully prepared to safely and efficiently perform his duties in a regular production section. These training sections may be used to indoctrinate new

miners and to train newly hired, but experienced miners, miners who are transferring from one job category to another, and any miners who require retraining because of unsatisfactory performance in a regular production section.

Because training sections are dedicated to training there is no "conflict" with production goals. The training staff consists of full-time foremen who were selected for their suitability as instructors and have received special instructor training. This is a distinct improvement over having overworked foremen trying to fit training in with other duties, or journeymen who are untrained as instructors, providing the training. In addition, various training materials and equipment, as well as actual production equipment, are available. Because the training section brings together time, talent and equipment, this form of formal OJT can be far more effective then informal OJT. Also, since there is no interference with production, as frequently occurs with informal OJT on a working section, and because one instructor can be providing training to a number of miners at a time (while other instructors can be providing individual attention to other miners as needed), a lower "true" cost can be realized from this type of training. Any production that results from the training activities of this section represents almost "pure" profit.

Finally, the one element that is most important in determining the effectiveness of this type of training is the almost absolute fidelity of the training environment to the work environment (which permits maximal transfer of skills, knowledges, etc., to practice). This is also the most significant potential problem of this method. In contrast to classroom and above ground simulated training sites, this training is being provided in the next most hazardous environment to the actual working section. Student errors seldom have serious consequences outside the mine. In a training section there is potential for serious accidents or injuries, however, recognition of these real-world hazards is a very important part of training and can be best provided in the mine. These hazards can be controlled and/or eliminated if proper caution is exercised. The accident potential for both the trainees and the working miners is even greater for informal OJT in a working section because of significant differences in skill levels, generally poorer and less well-controlled environmental conditions, and higher levels of activity.

Recommendation

Training sections should be a much safer alternative to providing informal OJT on a working section and, although the training risks are slightly increased over out-of-the-mine

instruction. In terms of effectively training the miners to recognize hazards and avoid accidents, the overall safety benefits that can be realized from a training section compared with out-of-the-mine settings probably favor the use of training sections. Wider use (and study) of training sections would be required to accurately assess the risks-costs-benefits of this method.

Recommendation

Daily or periodic training provided at the portal of the mine, particularly if it is carried out before the start of the actual work shift, may be convenient in certain circumstances, but generally will be less effective than if the training is carried out at the work place. Training carried out in the bath house, particularly if it is carried out after the completion of the actual work shift, may again be convenient under certain circumstances, but is also less likely to be effective than training that is carried out in the work place. Having closed-circuit T V presentations playing while the men are dressing and undressing, like safety posters, may have some, perhaps subliminal, value but is generally markedly less effective and is not an adequate substitute for training provided in other contents.

Recommendation

Above ground simulations of parts of the mine, when used in conjunction with actual and/or simulated production equipment, offer an effective means for providing training that is second only to training sections in the degree to which it is possible to achieve transfer of knowledge, skills, etc., to the work environment.

The above ground simulations are potententially safer than the training sections and there is a certain tendency (though not necessarily an inherent capability) to provide greater variation in the mining environment conditions, thereby enhancing the training effectiveness of this method.

The size of the investment made in simulating the mine will generally determine the extent to which this form of training costs more than a training section. However, there is a certain tendency to offset the se inherently higher costs associated with constructing the simulated mine by using less expensive simulated

machinery, whereas in training sections there is a tendency to employ the more expensive production hardware. These sorts of tradeoffs can net equal (or even lower) costs, but generally at the expense of training effectiveness.

Almost any simulation will be more effective then mere classroom instruction, or teaching machines; and can be more effective than training systems, but generally at the price of higher costs. However, because of the wide range of investments that can be made in either simulations or training systems, neither can be said to be inherently more cost-effective than the other. But, when one considers the amount of additional in-mine training required to achieve mastery of skills following classroom teaching, or machine simulator types of instruction, both above ground simulations and training sections can be potentially more cost-effective than other methods. If, however, the primary goal is merely to provide so many hours of instruction to remain in compliance with mandatory training requirements, the more cost-effective use of training sections, simulations, and training systems will never predominate over the widespread reliance on classroom and informal OJT training, whose "apparent" costs are low, but whose "real" costs can be quite high; most especially when the risks (and human costs) of ineffective training are factored into the equation.

Testing

Testing is employed as a part of various certification and qualification programs and in a few other fairly isolated instances. However, as a generalization testing is less frequently used than in other training contexts. There is also some evidence that the training for certification that is being provided prepares a miner to pass these tests rather than improve his safety knowledge and skills on the job.

Recommendation

Increased use of testing in association with virtually all mine safety training should be instituted, but primarily it should be viewed as a feedback device to the student and the instructor. Where testing is used in connection with certification and other related programs, the tests should be changed regularly and other security measures should be employed to ensure that the knowledges and skills being tested for are, in fact, being fairly and validly assessed. In terms of using

testing as the ultimate measure of training effectiveness, however, the accident records (inspection reports, etc.) are the only valid and reliable approach, since increased safety performance is the real goal and passing tests is not. For instance, an "effective" safety training program (as measured by tests), in the context of an overall poor safety program, will not necessarily be accurately predicted or controlled by any conceivable traditional testing program. Hence, testing (as it is commonly carried out) should be used to evaluate the training activity (and/or the individual student), but not as a measure of the likelihood of achieving the ultimate safety goal which is affected by too many other factors beyond the realm of training and testing.

Training Frequency

Much mine safety training is provided to miners once in their mining career and is never repeated and, hence, may be forgotten if not applied on a day-to-day basis. Since some of this material is not required in day-to-day operations, its loss from memory is not critical implying that some of the training now provided may actually be superfluous. Some of the material is, however, needed in emergency situations in which its loss can prove fatal.

Most training that is repeated tends to be repeated on an annual basis. It is notable that mines that retrain with greater regularity and at a steady rate throughout the year characteristically tend to have more effective safety training programs (i.e., better accident records), so there is certainly no doubt that retraining is required and pays dividends. But, in terms of cost-effectiveness, semi-annual retraining of each miner in the applicable topics would be unwarranted and might even be unfeasible. A continuous effort on the full range of topics seems to spread its impact throughout the work force even though only a few miners are being trained at any point in time.

Recommendation

Our findings indicate that annual retraining in critical skills, knowledges, etc. (that, generally are not reenforced on a day to-day basis and, hence are not remembered) is inadequate. Semi-annual retraining seems to be required for these topics. Moreover, they can usually be covered by means of safety meetings to all effected employees, to only those employees who fail a semi-annual test, or comparable criteria such as a systematic job task analysis. When determining a miners' train-

ing needs management should also conduct testing over time to identify which topics require semi-annual retraining, which topics can stand retraining on an annual (or longer) periodical basis, and which topics really can be imparted only once to new miners (or to miners first learning a specific job, etc.) and training-retraining schedules can be formulated accordingly.

ADDITIONAL RESEARCH

Mining Accident and Training Reporting System

The project achieved its basic purpose of producing a general description of various approaches to miner safety training in a cross section of the mining industry in late 1974. Analysis of the aggregate data reported to MESA for this training from 1972 through mid-1974 developed several interesting insights into the effectiveness of this training in terms of fatal and non-fatal injuries to miners. The statistics confirm the basic hypothesis that safety training (in the accident prevention sense) does lead to reduced injury rates. This is especially true where the specific objective of the training is to develop awareness of job hazards and the ways to avoid or eliminate them and, thereby, cause increased adherence to safe work practices. It was also shown that the potential returns in reduced lost time from injuries are large with respect to the training investment.

Difficulty encountered in relating data from the two different reporting systems for mine injuries and miner training indicates that recommended revision to both systems is desirable. The most common critique of mine operators concerning the data analysis deals with the inability of the reporting systems to produce accurate measures of activity throughout the industry. Injuries are now reported on a form from which the situation involved in the accident is identified in detail when the statistics are tabulated. Time, place worker identity, job assignment, experience, mining methods, mining task being carried out, machinery identification, mechanical failures, and many other pieces of information facilitate tabulation of the conditions related to mine injuries. However, this information can fail to identify why the accident happened. The current reporting system has a place for noting unsafe acts contributing to the accident, but this information seems to be lost when aggregate injury statistics are compiled. Yet review of narrative reports of 51 fatal injuries from 1970 through 1973 discloses the following comments:

- "...turned one crosscut too soon...did not have lights operating... (haulage)
- ...draw rock fell from the last row of bolts inby...covering the victim with the exception of his right arm. (fall of face, rib, or side).
- ...when his left hand came in contact with a bare conductor... (electrical).
- ...was not one of the crew...was standing out of view of the shovel operator. (other).

- ...failure to slope the grade wall at a sufficient angle... (sliding/falling material).

- ...had a leak in the jacks...turned them on...the area was filled with an oil mist...fault in the cable...grounded the 440 power...and ignited the most of oil around the victim. (explosion of gas or dust).

- ...lost control of the tractor...went over embankment...over-turned and pinned the victim...(haulage).

- ...increased his speed to pass...when the victim for some unknown reason started to pull over into his left lane. (haulage).

- Evidently he was not in the cab of the motor when he was trying to move it...(haulage).

- This time he was able to tram into the crosscut but without providing sufficient clearance for himself. (striking or bumping).

- He was evidently not sitting in the cab...when his head hit the bottom of an overcast...(haulage).

- ...all workmen, including the deceased, had repeatedly tested this piece of rock, and in the judgment of all, it was safe... fell, partially covering him...(fall of face, rib, or side).

- ...was trying to free the shell with a pick...when the face turned over covering him completely. (fall of face, rib, or side).

- ...pulled three switches on the outside end of the transformer and thought he had cut off the power. (electrical).

- ...he walked out into the area...42' long and 24'wide...un-supported and which had been previously loaded out. (fall of roof).

- This cable was dislodged from its hangers by a rail that was being unloaded 425 feet away. (sliding/falling material).

- ...ran across the road in front of the haulage truck...(haulage).

- As the victim started to position his side of the bolter to put up a bolt, it struck him...(machinery).

- . . . was standing on the belt when. . . knocked unconscious and transported by the belt to the coal bin and then into the coal car. There was a belt lock out safety switch within 15 feet. . . (machinery).

- The victim for some unknown reason stepped onto the framework. . . and inadvertently placed his foot on the moving belt and was pulled into the tail roller. (machinery).

- . . . the roof bolt wrench slipped off the 5 foot auger and struck the deceased. . (machinery).

- . . . the blower fan went off. . . thinking that all power was pulled, took hold of the loose energized phase lead. . . (electrical).

- . . . must have been examining the broken chuck under unsupported top about 5 feet beyond the roof bolts. (fall of roof).

- . . . did not know one of these men had hooked the cable to the tractor. . . started to move. . . causing the arch to fall, (sliding/falling material).

- . . . had told. . . to go behind and push. . . also told. . . to pull the truck out. . . were in between. . . to connect the tow cable when. . . pushed the truck. . . smashing. . . (machinery).

- . . . was facing the machine, with his back to the direction. . . he ran into the rib of an entry at the corner of the crosscut pinning himself. . . (haulage).

- Rather than stopping the buggie, as he evidently thought it would, the bumpers didn't meet and the buggie ran under the mantrip jeep. . . (machinery).

- He pulled down a small piece of rib coal and it released top rock, which fell striking the victim. . . (fall of roof).

- . . . he split the tram cats causing. . . the back of the machine . . . moved quickly crushing him against the coal rib. . . (machinery).

- . . . inby the crosscut 70 feet. . . only loaded 3 buggies when the roof fell. . . complete piece fell that had not been bolted. . . had sounded the top and it was solid. . . had examined the place only 15 minutes prior. . . the place was safe. . . was operating the ripper 7 feet beyond the last row of bolts. . . he expired at. . . (fall of roof).

- ...neither he nor the victim noticed anything out of the ordinary... the victim told him to watch this brow because it was bad...saw that the brow was indeed bad...turned to warn him...the top coal had already struck the victim...(fall of face, rib, or side).

- ...switch was inadvertently left in the "on" position...the conveyor began to run...victim hurried to turn it off...right foot on the shuttle car cabdeck and his left foot on the mine floor...he touched the shuttle car with his hands, he shouted "its got me"...(electrical).

- ...examined the roof and made gas tests 10 minutes prior to...moving loose coal...when the roof fell and killed him. (fall of roof).

- ...while attempting to cross the bottom layer of 72 inch wide conveyor belt...they were not aware...had seen the victim... fifty feet below, before the accident...it threw the victim under a...(machinery).

- ...he was on the ground on the right of the machine in view... was moving toward the right shoe to get on it...much easier... common practice...because concerned and went to look for him...on top of the shoe crushed...could not understand how... (machinery).

- ...picked up the tire with a fork lift...noticed a spacer was missing from the hub...stopped the fork lift and tire within about 5 feet of the hub...remained in this vertical position for ...ten minutes...for some unknown reason the tire began to fall...driving his chest into the hub..." (sliding/falling material).

In summary, there was some unsafe act or behavioral cause contributing to seventy percent of the 51 fatalities that would not be apparent from analysis of the information normally tabulated in accident statistics. These are the kinds of acts that should be addressed with training programs as many of the accident prevention courses do. Also note that there was only one example of roof or rib fall where the situation was acknowledged to be bad. These occurrences of "risk taking" and other human errors represent some of the cases where the victim was unlucky. A valuable tool for planning and monitoring safety and training programs would be provided if the real extent of both behavioral and situational accident causes were to be incorporated into the system for accident and injury statistic tabulation and analysis. The situations are currently well documented, but behavioral factors can only be inferred from the situation.

Recommendation

Development of a revised set of coding options for the existing report format is an approach that warrants consideration. The new coding options should be based on those behaviors and mine conditions which can be made the subject of education and training or inspection and enforcement actions. Analysis of accident statistics and mining job hazards has already done a great deal toward the identification of the behavioral and situational causes of injuries. Reduction or elimination of accidents through training and enforcement actions has also been supported by this data analysis. However, these actions are required, planned, conducted, reported, and monitored in a context that is often unrelated to an accident cause, relates to any part of some cause, or relates to several distinct causes. Orienting both injury reports and training or enforcement activity reports to a common set of factors that cause accidents will provide several advantages over the existing reporting systems. A well designed system should bring more uniformity in reporting as well as more accurate information. There also seems to be potential for making the reporting require less administrative effort in both the submission and compilation of the information. Since the basis of the systems should be the main situational conditions and behavioral events that can and should be changed, all concerned parties will gain better information on the nature of the mine safety problem, the activity being directed at each aspect of the problem, and the results (effectiveness) of that activity.

It is obviously easier to point out the need for and outline the advantages of a change to existing report formats for injuries, training, and even enforcement activity than it will be to develop a better system. We know that MESA has proposed a change to the injury report form and that the BCOA and UMWA apparently desire a change. The interests of the operators, union, and MESA in changed reports are not sufficiently common to allow implementation of a new system that will satisfy everyone soon, if ever. The mine operators are not eager to report anything beyond what the law requires because that report may eventually be used against them in enforcement or civil court actions. The union will be for full disclosure by the companies, but is not likely to endorse anything that also provides for indicating that an injury could have resulted from the actions of anyone but a company man. There can be big debates over what was the cause and who can make that determination. MESA must compromise its need for information with what the Solicitor's Office can get past expected legal challenges over what is reportable or the definition of lost time and also must eventually obtain OMB approval. The result is a lot of work for three groups of lawyers

that has a remote chance of eventually directly addressing the basic issues of mine safety.

Recommendation

Conduct a three phase program to (1) develop improved accident cause and training objective reporting classifications, (2) test the revised classifications with historical data to develop a tentative reporting format(s), and (3) field test the new reports format in a cross-section of mine environments.

As a starting point for revised classifications for basic and immediate injury causes the following listings of hazardous conditions, hazardous acts, and contributing stresses as presented in an OSHA course for supervisors may have merit:

Hazardous Conditions

Some of the kinds of hazardous conditions that commonly cause accidents and exposures to health hazards in the workplace are:

- improperly guarded equipment
- defective facility
- hazardous arrangement
- improper illuminations
- improper ventilation
- unsafe dress or apparel
- inadequate maintenance
- improper labelling, transport or storage of hazardous substances
- excessively high noise level
- extreme heat, cold, humidity or dryness
- excessive vibration

Hazardous Acts

The hazardous acts that commonly cause accidents and exposures to health hazards in the workplace are so well known that it is possible to prepare a simple list that will cover a majority of the situations.

- operating without authority
- operating or working at unsafe speed
- making safety devices inoperative
- using unsafe equipment
- loading or mixing in unsafe manner
- taking unsafe position
- working on moving or dangerous equipment
- distracting co-workers or being distracted
- failing to use proper clothing

Contributing Stresses

Types of stresses which are suspected of contributing to accidents and injuries but which are not so well documented are:

- heavy responsibility
- rapid working speed
- high volume output requirements
- combination of many complex steps
- emotional stress
- monotony

Multivariate Analysis of Mine, Miner, Enforcement, Training and Injury Data

The data analysis carried out in this program was intentionally limited to examination of the relationship between measures of training effort and mine injuries. Cases that strongly fit the hypothesis that safety training leads to reduction of injuries were considered effective training and the cases that did not fit were identified as examples of ineffective training programs. Descriptions of the training programs were then compared to determine what features tend to be associated with effective results and not with ineffective results. When it was found that the training and way in which it is conducted is virtually identical for both the most and least effective mines, a number of other factors were examined in search of the reasons why the apparent training effectiveness varies as it does. This shift of the research strategy could produce only limited conclusions because the original aggregate data had not been set up to use multivariate analysis techniques that could efficiently control for the other factors that either influence injury rates directly or are intervening influences on the relationship between training and injury rates.

Recommendations

Additional analysis using multivariate techniques with a reorganized and expanded set of aggregate data would produce stronger and more definitive explanations for the variations of training effectiveness. There are three data preparation tasks and two analysis tasks that will build on the past work and knowledge of the problems and limitations of the available data. The first data preparation task is a simple recoding of the training and injury data used in the 1974-75 study program. A second task is to increase the number of metal and nonmetal mines and the number of western surface and underground coal mines in the data base. The time span of the data would also be extended through 1975 in this second data acquisition task. The third data preparation task is to incorporate into the aggregate data set factors such as mine characteristics, the training not reported in the MESA system, enforcement actions, and miner attitudes. One analysis task would be limited to a multivariate search for the factors that explain the rank order of overall training effectiveness produced in this study. This analysis could be expanded to perform the same effectiveness evaluation for all the individual training courses and then the multivariate analyses needed to explain the variations in effectiveness. The other aspect of the data analysis would be use of regression or other multivariate techniques such as discriminate function analysis to identify the relative importance of all the factors that appear to explain injury experience. Study outputs will be a tested method and programs for routine evaluation of training efforts and various models to compare the relative returns from several areas of effort to achieve greater mine safety.